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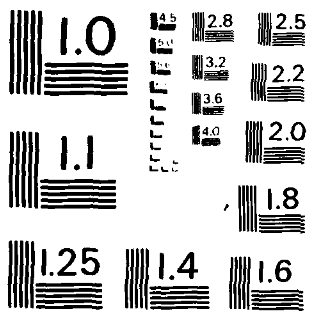

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: AFIT/CI/NR 83-54T	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): An Exploratory Study of the Use of An Inexpensive Cordless Telephone as a Part of a Data Communications Link	5. TYPE OF REPORT & PERIOD COVERED: THESIS/~~DISSERTATION~~
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Edwin Buford Morgan, Jr.	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: AFIT STUDENT AT: Auburn University	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: AFIT/NR WPAFB OH 45433	12. REPORT DATE: 26 Aug 1983
	13. NUMBER OF PAGES: 120
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASS
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

APPROVED FOR PUBLIC RELEASE: IAW AFR 190-17

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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THESIS ABSTRACT

AN EXPLORATORY STUDY OF THE USE OF AN INEXPENSIVE CORDLESS TELEPHONE AS A PART OF A DATA COMMUNICATIONS LINK

Edwin Buford Morgan, Jr.

Master of Science, August 26, 1983
(B.S., University of Oklahoma, 1963)

130 Typed Pages

Directed by J. Tyrone Gibson

This was an exploratory study performed to identify some of the variables contributing to the accuracy of data transmission using a cordless telephone as a part of a data communications link. The experimental design used was a fractional factorial design using two, one-quarter replications of all possible combinations of the eight variables studied.

Independent variables manipulated included distance, height of receiver, antenna length, and antenna angle from the vertical. Other independent variables included the presence or absence of operating fluorescent lights, an intervening metal cabinet, an intervening wall and door, and an intervening human body. The dependent variable measured was the percentage of 13 character number strings

received which matched identical records previously stored in a computer.

The cordless telephone used in the study was a Radio-Shack brand DuoFone ET-330 costing approximately $200. Other equipment used included an MSI/66 Portable Data Terminal, a Hayes Stack Smartmodem and a Data General Nova 4X minicomputer.

Analysis of the study results indicated that 15 variables and interactions of variables contributed significantly to transmission accuracy rates. These 15 factors were used to construct a linear model which can be used to predict data accuracy rates in certain situations involving the eight variables studied.

AN EXPLORATORY STUDY OF THE USE OF AN INEXPENSIVE CORDLESS TELEPHONE AS A PART OF A DATA COMMUNICATIONS LINK

Edwin Buford Morgan, Jr.

A Thesis

Submitted to

the Graduate Faculty of

Auburn University

in Partial Fulfillment of the

Requirements for the

Degree of

Master of Science

Auburn, Alabama

August 26, 1983

AN EXPLORATORY STUDY OF THE USE OF AN INEXPENSIVE CORDLESS TELEPHONE AS A PART OF A DATA COMMUNICATIONS LINK

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INEXPENSIVE CORDLESS TELEPHONE AS A

PART OF A DATA COMMUNICATIONS LINK

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Edwin Buford Morgan, Jr., son of Edwin Buford and Mary Merle (Arline) Morgan, was born July 31, 1945, in Gainesville, Florida. He attended Lawton Public Schools and was graduated from Lawton High School, Lawton, Oklahoma, in 1963. In September, 1963, he entered Cameron State Agricultural College and received the degree of Associate in Arts in June 1965. In September of 1965, he entered the University of Oklahoma and received the degree of Bachelor of Science (Pharmacy) in June, 1968. In June, 1968, he was commissioned as an officer in the United States Air Force and entered active duty in October, 1968. He completed the Air Force Squadron Officer's School in 1978 and the Air Command and Staff College in 1979. In 1981, he completed the National Defense University's National Security Management Course. In September of 1981, he entered the Graduate School, Auburn University. He married Marilyn Ann, daughter of Ray Anthony and Ziranell Marian (Jarred) Moreau in August, 1968. They have one son, Stephen Patrick and two daughters, Mary Elizabeth and Kathleen Marie.

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I. INTRODUCTION

The High Cost of Health Care

The continuing rise of health care costs has become, in this period of economic instability, a matter of nationwide importance. Between 1960 and 1981, national health care expenditures have risen from 26.9 billion to 286.6 billion dollars. This represents a ten fold increase over the twenty year period. Table 1 illustrates this growth and shows these expenditures have increased so that

Table 1

GROSS NATIONAL PRODUCT AND NATIONAL HEALTH EXPENDITURES

YEAR	GNP	EXPENDITURES ($ in billions)	% OF GNP
1960	503.7	26.9	5.3
1965	691.0	41.7	6.0
1970	992.7	74.7	7.5
1975	1,549.2	132.7	8.6
1980	2,626.1	249.0	9.5
1981	2,925.5	286.6	9.8

they now account for 9.8% of our total Gross National Product (GNP). This is up from 5.3% in 1960 (1).

During this same period, 1960 to 1981, the consumer price index for all goods and services rose from 88.7 to 272.3, a three fold increase, while the consumer price index for medical care has increased by a factor of almost 4 (3.75), from 79.1 to 295.1 (2). Since 1975, national expenditures for health care have risen at an annual rate of 14.0% while the cost of hospital care, the largest component of national health care costs, has risen at an even higher average annual rate of 14.6% (3,4).

Within the category of hospital expenditures, higher wage rates have accounted for the largest portion of the increase. Data published by the Department of Health and Human Services indicate that wages of hospital employees have risen since 1977 at an annual rate of 43%. The next highest component of hospital costs has been the purchase prices of goods and services. These costs have risen at an annual rate of 38%. Table 2 provides this data in more detail (5).

Federal Government expenditures on health care, as reported in the President's 1983 Budget Message, are expected to reach $78.1 billion in Fiscal Year 1983. This will represent an increase of $4.7 billion over 1982 outlays, a 6.4% increase. Medicaid and Medicare, which account for 93% of Federal health costs, have increased

at an average annual rate even higher than that of total national health care costs. These expenditures have, between 1970 and 1980, risen at an average annual rate of 17% (6).

Table 2

AVERAGE ANNUAL PERCENT INCREASES IN HOSPITAL INPATIENT EXPENSES PER PATIENT DAY

	1971-74	1974-77	1977-80
AVERAGE ANNUAL % INCREASE	10.7	15.2	12.2
PERCENT OF TOTAL INCREASE			
WAGE RATES	36	39	43
PRICES OF PURCHASES	28	19	38
HOSPITAL EMPLOYEES	11	11	9
OTHER EXPENSES	25	31	10

These huge expenditures, high rates of increase, and the large portion of the GNP devoted to health care and hospital costs would indicate that legislative and regulatory agencies will continue to demand strict cost control and improved management of resources in the health care industry. In order to remain competitive and responsive to social and governmental demands, the hospital industry must increase its productivity, efficiency of operation and management of resources.

One possible method to improve current medical management practices would be to adapt to medical functions management engineering and operations management techniques which are widely used in other industries. These techniques, which include inventory planning and control, ABC inventory analysis, materials requirements planning, systems analysis, productivity measurement, and work and facilities design and planning are now receiving more attention in hospital literature. These techniques have been used to control both inventories and operations and it is possible that they could be applied throughout hospitals as aids in managing not only the traditional resources of funds, personnel, and supplies but also information resources as well. These tools might prove useful in the management of all information resources including data, hardware, and communication systems.

Information Management

Within the hospital industry, a large number of institutions still use traditional manual methods of information and records management. Input into these information systems, which include the collection, storage, retrieval, communication, reporting and management of data, is performed manually through the preparation of forms, record sheets, requisitions and charge slips. Information, when required, must be

retrieved manually by searching through an alphabetic or numeric indexed file. The amount of information stored in these files, the physical space they occupy, and the time spent to maintain and use them can be enormous. Retrieval of information and its communication to the point of need are major difficulties with these manual systems (7).

The value of using computer systems to perform these repetitive tasks has been widely recognized in the business community; however, few studies have been identified which document their cost effectiveness in hospitals (8). One possible explanation for this lack of adequate cost-benefit analyses may be the difficulty in separating the effects or benefits of the automated system from the high costs and inefficiencies of the methods used to collect, record, communicate and enter data into the manual information system. R. M. DuBois has stated that in the past it has been impossible to make definitive statements on how automated hospital information systems affect either quality of care or costs. This is true, he states, because of the inability to assess the impact of automated hospital information systems on any variables other than those involved in health care processes (9). Measures have not been identified and adequate studies have not been carried out to identify sytem effects on the outcomes of health care or on the collection,

use, flow, transmission, communication or management of data or information within hospitals.

Data

Data is a general term used to describe any or all facts, numbers, letters or other symbols (10). They represent statements, ideas, events or other observables which may be true and accurate but in a particular context have little meaning or relevance (11).

A data processing or information system (either manual or automated) is "an aggregate of elements that exists conjointly for the purpose of collecting, organizing, storing, retrieving, interpreting and diseseminating information" (12). A data processing system performs the operations outlined in table 3 (13).

Table 3

DATA PROCESSING OPERATIONS

DATA COLLECTION
DATA ENCODING
DATA CLASSIFICATION
DATA STORAGE
DATA RETRIEVAL
DATA SUMMARIZATION
DATA ANALYSIS
DATA OUTPUT OR COMMUNICATION

Information

The purpose of these operations is to generate information. Information is defined by B. J. Whittemore as "that subset of data, which after having been evaluated with respect to some purposeful activity, has been found useful" (14). He states that "the extent to which information is useful depends on the decision maker (the user), the decision in question (the use), and the time at which the information is available."

G. J. Brabb defines information as "communicated knowledge expressed in a form that makes it immediately useful for decision making." That is, information is a new fact or a fact previously unknown to a decision maker. It is presented to the decision maker in a form that he or she can understand and assimilate. It is useful in making a decision, choosing an option, or reaching a conclusion and, it is available in time to be used in making the required decision. Information then, as do goods in commerce, posesses the characteristics of time, place, posession, and form utility (15).

Utility is defined as the ability to satisfy a need or desire. The marketing discipline recognizes the four categories of utility listed above as characteristics of goods or products sold to satisfy users or consumers needs or desires. To fulfill a need or satisfy a desire, a good

has to be available to the consumer (posession utility), when needed (time utility), where needed (place utility), and of the type required to be used or consumed (form utility). If one or more of these utilities are not present, the need or desire will not be completely fulfilled (16).

The Hospital as a System

A hospital can be thought of as a system existing to provide health care to its patients and other benefits to employees, stockholders, and other claimant groups. This hospital system in turn is composed of numerous levels of subsystems and subsubsystems which perform the necessary tasks and functions which enable the hospital to provide its services and benefits. Examples of some of these lower level system components would include the nursing care subsystem, the pharmacy service subsystem, the prescribing subsystem, the drug delivery subsystem and the many subsubsystems within each of these which perform the routine tasks and controls at the operating level of the institution.

Decision Making

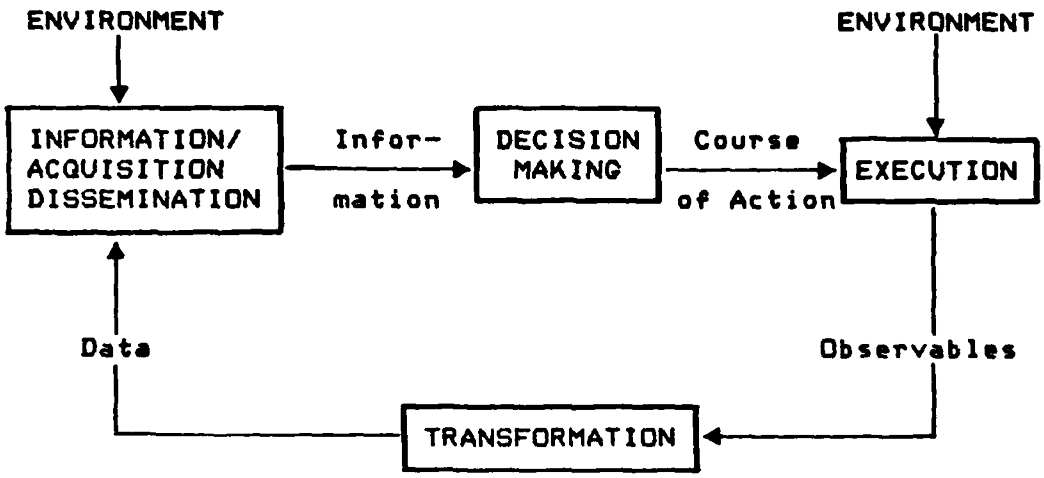
At this operating level, many of the tasks required of hospital personnel require professional judgement and decision making along with performing the activities

necessary to carry out these judgements and decisions. This decision process can also be viewed as a decision system with inputs from many sources. Commonly, the inputs include the results of previous decisions or choices as well as observables from the environment. Figure 1 illustrates this decision process. This system model can be applied to any decision process. Input into the system can come from outside of the system, the environment, or from data resulting from events within the system itself.

The major input into the decision making function of this model is information and information is composed of data. Since information posesses the characteristics of goods in the market place and data is the raw material from which information is derived, it is not difficult to think of a collection of data, or data base, as an inventory upon which decision makers within a medical facility must draw in order to perform their work of making appropriate decisions.

Data as Inventory

The operations involved in the creation and maintenance of this data inventory are the same functions found in other more traditional inventory or logistics systems (18). Table 4 makes these comparisons.



Adapted From Whittemore (17)

DECISION PROCESS MODEL

Figure 1

Table 4

COMPARISON OF DATA PROCESSING ACTIVITIES TO LOGISTICS/INVENTORY FUNCTIONS

DATA PROCESSING ACTIVITIES	INVENTORY/LOGISTICS FUNCTIONS
COLLECTION, GENERATION OR PURCHASING	PROCUREMENT
RECORDING/ENTRY	RECEIVING
STORAGE	WAREHOUSING
RETRIEVAL/COMMUNICATION	ORDER PROCESSING
OUTPUT/TRANSMISSION	DISTRIBUTION/SHIPPING

In traditional inventory systems, the procurement of goods and services is similar in concept to the collection of data at its source, the generation of data within an information system, or the purchase of data from commercial suppliers of data services. The receiving of goods in a warehouse is similar to the recording of data onto manually prepared forms used for entry into an automated system or to direct entry of data into the system. A comparison is easily made between the warehousing of goods and the storage of data. The processing of materials requisitions or purchase orders, including the removal of items from the warehouse and preparation for shipping, is similar to retrieving data from its storage location and

forwarding it to an output device or location. Finally, the distribution or shipping of completed orders is similar to the output, display or transmission of data or information in an *automated system*.

Data inventories possess the same characteristics of cost, value, and scarcity as do inventories of more familiar resources (19). Data inventories, as do other inventories, have carrying costs associated with them. There are opportunity and other costs associated with the delay or unavailability of needed data or information and there are losses caused by erroneous or incomplete data (20).

Data occupy space within the hardware devices used to store them. There are acquisition, maintenance, and overhead costs associated with these devices. There may be opportunity and overhead costs associated with the use of this storage to maintain unnecessary or outdated data to the exclusion of more useful or valuable data. There are in addition, other costs associated with the storage of the same data in more than one location. In both automated and manual systems, the cost of this redundancy will increase storage costs. Problems will be introduced in the maintenance, accuracy and reconciliation of the individual data items. As a result the possibility of error is greatly increased (21).

Finally, there is a high personnel cost associated with the manual collection and processing of data within a hospital. This is in addition to the cost of time spent in the communication of information and the cost of errors caused by missing or erroneous information (22,23).

The data inventory, because of its necessity in the operation of the organization and the costs associated with its maintenance, should be considered of equal importance and value to other organizational resources such as financial, personnel, plant, equipment etc (24). This resource may, upon closer examination, be even more significant to the organization since it is information, made up of data, which are the inputs into the management decisions which control the other resources (25).

General Problem

The traditional, manual data processing or information systems found in hospitals are error prone, slow, inefficient and costly. The following problems have been identified in manual hospital information systems (26-34):

- High labor cost to collect, record and transfer data.
- Unrealistic demands on human memory.
- Lack of coordinated use of medical information.
- Lack of logical organization of information in medical records.
- Data not available when needed.

- Data not available where needed.
- Data not readily available in the form needed.

Partly as a result of these problems, health care systems and subsystems are difficult to control. In large part, this is because neither the health care system nor the information subsystem operating within it can provide reliable or efficient feedback or control notification to those personnel performing care or management related tasks and operations (35). This lack of feedback can be partially corrected through the use of improved communication and communication systems (36).

Improvement of management, efficiency, and effectiveness of hospital operations through the use of management engineering and operations management techniques alone may not be sufficient. Changes may also be required in the areas of managerial and operational control. Management control is a process performed by managers to insure that resources are obtained and used efficiently and effectively. Operational control is a process of monitoring specific tasks to insure that they are carried out efficiently and effectively (37).

The goal of these control processes should be to obtain optimum relationships between resource inputs and desired outputs (38). This goal is applicable to the management of all hospital subsytems including the financial, patient care, and information subsystems. Two requirements

must be met to achieve this goal. First, resources employed must be acquired at the lowest cost consistent with quality and reliability. Secondly, managers and operational personnel must receive feedback of problems within the various subsytems in time to prevent significant deviations from the desired results or outcomes within those subsystems.

It follows then that to obtain data and information at the lowest cost is a major objective which should be sought in attempting to better manage the information resource. A second major objective should be the communication of data and information from the point of collection to the point of use at the lowest cost consistent with accuracy and reliability. To achieve this we must look at the cost of data collection, transcription and communication and attempt to identify possible improvements in the operation and cost effectiveness of the information system.

It is obvious that the cost to collect a datum or a parcel of information should not exceed the value of that datum or information (39 - 45). This value should be evaluated on the ability of the datum or information to reduce risk or uncertainty in the decision process, its impact on patient care, its mandated collection for regulatory or financial purposes, and/or its ability to aid in controlling an operation or process. For an

information system to be operating at its optimum level, the net difference between the cost of obtaining the information and the expected value of the information should be at a maximum (46). One method to increase this difference is to collect and communicate the data needed in the information system at the lowest cost.

Once a decision has been made to control a system it is reasonable to expect that the cost of controlling the system should not exceed the value obtained by controlling that system. This means that a net loss in value will occur if more resources are expended in obtaining information and implementing actions required to maintain system outputs within set standards than can be saved by maintaining outputs within those standards. This concept reinforces the objective of obtaining and communicating data at the lowest cost consistent with accuracy and reliability.

Several possible alternative methods of improving the hospital data entry and communications subsystems are available. These alternatives would include, among others, the use of additional personnel, the addition of hardwired computer input-output terminals throughout the facility, distributed data processing networks, the application of sophisticated telecommunications technologies, or a combination of these. Any effort to increase the cost effectiveness of the information system must

evaluate each alternative on the basis of performance and cost over the expected life cycle of the alternative.

The alternatives listed above of hiring additional personnel, hardwired computer terminals, distributed networks, and sophisticated telecommunications technologies all carry with them the possibility of significant expenditures over a five to eight year life cycle. The use of less costly data entry/output devices with an existing or low cost communications link would provide another, possibly more cost effective, alternative if the necessary accuracy, reliability and timeliness could be provided. The use of portable data entry terminals, cordless telephones, and existing telephone circuitry may be able to provide the required communications capability with a minimum investment cost.

Problem Statement

This exploratory study will attempt to identify some of the variables associated with the use of a relatively low cost commercially available hand held voice grade cordless telephone to provide a communications link to a host computer. The specific purpose of the study will be to investigate the feasibility of using this type equipment as part of a data/information collection and communication subsystem. In particular, it will try to answer the question of what variables influence the accuracy

of data transmitted to a computer using a cordless voice grade telephone as a part of a data communications link.

II. REVIEW OF THE LITERATURE

The Concept of Data

In order to understand the role of data and information in decision making and control of organizations, we must first define data and describe some of its characteristics. M. J. Riley in a text on Management Information Systems defines data as statements, facts or figures that may be accurate but when considered alone have little meaning or relevance (47). He states that "data are language, mathematical or other symbolic surrogates that are generally agreed upon to represent people, objects, events, and concepts " (48).

In other words, data are unassociated and/or unrelated facts and are the raw materials from which information is produced. Since bits of data, taken alone, are unrelated or unassociated not all data will, in any particular circumstance, be capable of producing relevant information (49).

Oxenfeldt in describing decision making and the decision making process has defined data as statements that may be true and accurate but in any particular context have little meaning or relevance (50). This agrees well

with the previous definition and establishes two of the characteristics of data when combined or processed into information. These are accuracy and timeliness.

Data may be obtained from the environment in the form of the results of empirical research or through observation of events. A fact or bit of data when stored or communicated represents in some symbolic form something which has happened in the real world and can be verified (51). The extent to which the bit of data represents that which has occurred is a measure of the accuracy of that datum. The extent to which the datum represents the most current state of that which is or has occurred represents the timeliness of that datum.

Whittemore in a PhD dissertation developing a generalized decision model, defines data as "the transformation of observable environmental phenomena into facts, figures, charts, tables, graphs, or recorded statements or accounts." This definition is expanded to include those non tangible observables which the human mind creates including judgement, estimation and intuition (52).

Data are factual and objective. Since facts must be represented in some symbolic form to be stored or communicated, figures, alphabetic characters and other drawn symbols are basic elements of data. These are often meaningless until properly arranged or structured (53).

Data may be represented in many forms including oral, written, drawn, or as stored bits of electricity or magnetic charge. The concept of data must not be limited solely to digitalized data. All data entered into computers and stored in digital form had to exist in some form either digital or nondigital prior to entry (54). The key concept is that each datum represents a fact, event, value, or concept and may have little or no meaning when taken alone or out of context.

The Concept of Information

The definition and description of information proceeds from and includes the concept of data in that information is data made useful in a particular situation or problem. Brabb defines data as knowledge communicated to a decision maker (user) in a form which enables that knowledge to be immediately useful in making a decision (55). That is, the data may be applied to the making of a decision or the solving of a problem without further processing to determine its relevance or applicability.

Weinmeister carries this definition further and states that information is an arrangement of data and nondata which provides sufficient background to develop options and make decisions. In this definition, nondata includes subjective factors such as estimates, judgements and other nonobservable factors (56).

Whittemore proposes that data does not become information until it has been related to a "purposeful activity" and has been judged useful in performing that activity. The usefulness of a set of data when converted into information will depend therefore on the activity to be performed, the time at which the information is available in relation to the time at which the activity takes place, and the opinions and values of the decision maker who receives the information (57).

This definition is echoed by Oxenfeldt who states that "accurate statements must be made relevant to a specific problem before they become information" (58). He describes two processes which are required to transform data into information. First, useful pertinent data must be separated from the larger set containing irrelevant useless data for the specific problem being addressed; next, the data selected must be analyzed and interpreted and generalizations or inferences supported by that data must be drawn.

The information which results from this process can then be used to serve several different purposes. Information can be used to describe, to explain, to predict, to evaluate, or to invent (59). The use to which the information generated in the conversion process will be placed will determine what data is necessary, relevant and or useful in any particular problem or decision.

Another author, Riley, writing on management information systems states that information is produced from data as a result of modeling, formatting, organizing, or converting in such a way as to increase the knowledge of the recipient (60). This definition, as opposed to those presented earlier, does not seem to imply the need to relate data to a specific problem, activity, or event in order to become relevant information.

In developing the topic of information and its use in the making of management decisions, Riley lists a number of criteria which information must meet to be useful (61). These are listed in Table 5. To determine if information meets these criteria, the user must make judgements of the data composing the information and how that data relates to the factors listed. This requires the data to be related to the specific problem or question at hand and therefore reinforces the definitions previously stated.

Anthony and Dearden in their text on management control systems define information as anything which adds to knowledge. This may be a fact, a datum, an observation or a perception. By indicating that the fact must add to knowledge, they imply that the data which makes up information must be related to other data, information, situations or problems (62). They continue their description of information by stating that data which does

Table 5

INFORMATION CRITERIA

ACCURACY
COMPREHENSIVENESS
APPROPRIATENESS
TIMELINESS
CLARITY
FLEXIBILITY
VERIFIABILITY
FREEDOM FROM BIAS
ACCESSIBILITY
APPROPRIATE FORM
APPROPRIATE FREQUENCY
APPROPRIATE SCOPE
KNOWN ORIGIN
COST EFFECTIVENESS

not add to knowledge or which conveys an unclear message is not information but is noise. The process of converting data into information must weed out this noise in order to be effective.

Information can be categorized in several ways based on its source, the degree of formality of collection and communication, its intended use, and others. Within an organization, internal information is often categorized into three broad areas. These are accounting information, operating information, and control information (63). In this scheme, accounting information is derived by aggregating input data from throughout the organization into a single monetary measurement for comparison and analysis.

Operating information is that which is generated during the day to day working of the organization. Included is information concerning personnel and resource use and status. The third category, control information, includes plans of the objectives and goals of the organization, the measurement of the actual performance of the organization towards achieving these objectives, the results of comparisons between desired performance and actual performance, and feedback information to the organization to allow plans to be revised or performance changed .

Kraegel et al in their seminal discussion of hospital and nursing care systems comment that information is the

basic ingredient of every dynamic system. Information and the use of information determines what messages circulate within the system and between the system and the environment in which it operates. Information in the form of policies and guidelines directs the system towards the achievement of the objectives it wishes to accomplish (64). In most instances, the objectives themselves are information.

Information is vital to the control of any system or organization. Feedback information provides the regulation and control which helps constrain the system to operate within predetermined limits as it operates to achieve its objectives. Without feedback information there would be no control.

Decision Making

Whittemore describes decision making as a process which is the basic ingredient of purposeful activity. Each decision is an event, the making of a choice or judgement from among alternatives. In order for this decision event to take place, information must be available to the decision maker. At the basic level, the decision maker must have information indicating a decision is required along with additional information that there are a minimum of two alternatives and some idea of what the alternatives are (65). In order to make an effective decision, additional

information concerning the expected outcome of each of the alternatives is also required.

Information is therefore the input resource or raw material which is used in the decision process to produce a choice among alternatives - a decision. In discussing this concept, Whittemore explains that the making of decisions is the "raison d'etre" of information. It is captured, stored, processed and manipulated for the purpose of making decisions (66).

J. E. Starron has defined decison making as the selection of a course of action from among alternatives to resolve a specific problem. This agrees closely with Whittemore's definition. To achieve an objective or solve a problem, the decision maker must have knowledge of what the objective or problem is. He must have information that the present condition is not what is desired and what the results expected from the decision should be (67). From this and other information alternatives can be defined and a solution generated.

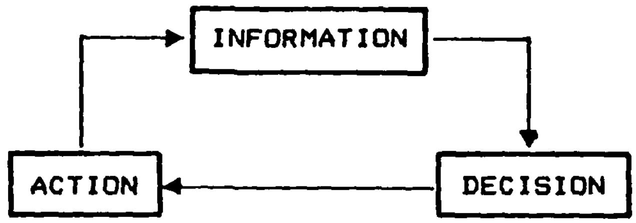
Hodge et. al. have written that management is a process, called decision making, which converts information into action (68). As in many other processes, the quality of the output (decision) may be influenced by the quality of the input materials (information). Other determinants of the quality of the ouput may include the conversion process itself and the values and opinions of the decision maker

(69). This proposition is supported by Weinmeister in his statements that the more pertinent the information available to the problem at hand the better the resulting decision (70).

Another definition is put forth by Russell Ackoff who sees decision making as a process which converts information into instructions. Instructions are defined as messages which are intended to effect the behavior of a system in such a way as to improve its performance (71). With this definition, decisions and decision making are closely related to the concept of control.

In its simplest form, a decision cycle consists of three functions as depicted in Fig 2. Information is the input into the decision process. In this process an output of action or information to direct action is produced. As the action result is performed, new information as to the result of the action is produced to become input back into the decision process. In reality the system is rarely this simple. Information inputs may come from many sources. Actions and their resulting information become inputs into many other cycles so that complex multi-looped networks of information interchange are formed.

The decision process itself is composed of three separate functions. These include the formation of concepts of a desired result or condition, the observation



Adapted From Hodge and Hodgsdon (72)

A DECISION CYCLE

Figure 2

of actual conditions, and the generation of corrective action (73). This view of the decision making process parallels closely the concept of a control system in which standards are set, conditions or outputs compared against the standards, and corrections made to enable the system to produce outputs which are within the set standards (74). In fact, two of the key elements in a control system are decisions. One is made to determine if outputs are within preset standards. A second is made to select the corrective action required to correct any deviations from preset standards or limits.

Herbert Simon has presented a set of three activities which are involved in the decision making process. Intelligence activities involve the observation of or searching for problems or situations which require a decision for their solution. Design activities are those

which are involved in the analysis of information and the definition of alternatives or courses of action. Choice activities are those which are used to select the desired solution, alternative or course of action from among those defined in the design activities (75).

Peter Drucker in "The Effective Decision," suggests that decision making involves six steps. In this schema a problem is first classified, then in a second step, defined. Next, the specifications or limitations which the solution must meet are defined. The fourth step requires a judgement of what is a "right decision" rather than what is only acceptable. The decision must then have included in it the actions or activities which will be required to carry it out . Finally, feedback information after the decision has been made is reviewed to examine the effectiveness of the decision (76).

Starron in developing a general model for executive decision making suggests that there are eight separate and distinct steps involved in the decision making process (77). The executive decision maker is encouraged to perform the following:

1. Monitor the problem domain.
2. Select a problem requiring management attention.
3. Define the problem in terms of:
   a. Condition.
   b. Cause.

c. Effect.

d. Time.

e. Place.

4. Identify alternative solutions.

5. Evaluate and cost out alternatives.

6. Select the "best" alternative.

7. Implement the decision.

8. Evaluate the results of the decision.

In each of the three models of decision making presented above, two similarities stand out. First, all three models involve the collection or review of information in the beginning of the process and the generation of new information at the end of the process. For example, in Starron's eight step model, steps one through four involve the gathering of information on which to base the decision. Steps five through eight and possibly step four as well, involve the generation of new information. The second shared characteristic in these models is the parallel between the decision process and the control process.

The Concept of Control

Johnson, Kast, and Rosenzweig define control as "that function of a system which provides adjustment in conformance to a plan; the maintenance of variations from system objectives within allowable limits (78). Weiner in

discussing control in the context of dealing with human beings, defines control as the sending of messages which effectively change the behavior of the receiver of those messages (79). Another, although similar, definition is set forth by Riley, who has defined control as the insuring that activities produce desired results (80).

A control system is one whose purpose is to attain or maintain a desired state or condition. In order to achieve this purpose, a control system is described by Anthony and Dearden as being composed of four elements. These are a detector, a selector, an effector and a communicator. These elements are depicted in Figure 3 (81).

In operation, the detector functions to identify or measure the output parameter being controlled. The selector determines if the output or parameter measure is within preset standards or limits. If not, the significance of the variation is determined. The effector is the element capable of directing or bringing about changes in the standards or operations of the system being controlled to bring the output or parameter back within limits. The fourth element, the communicator, transfers information between the other elements.

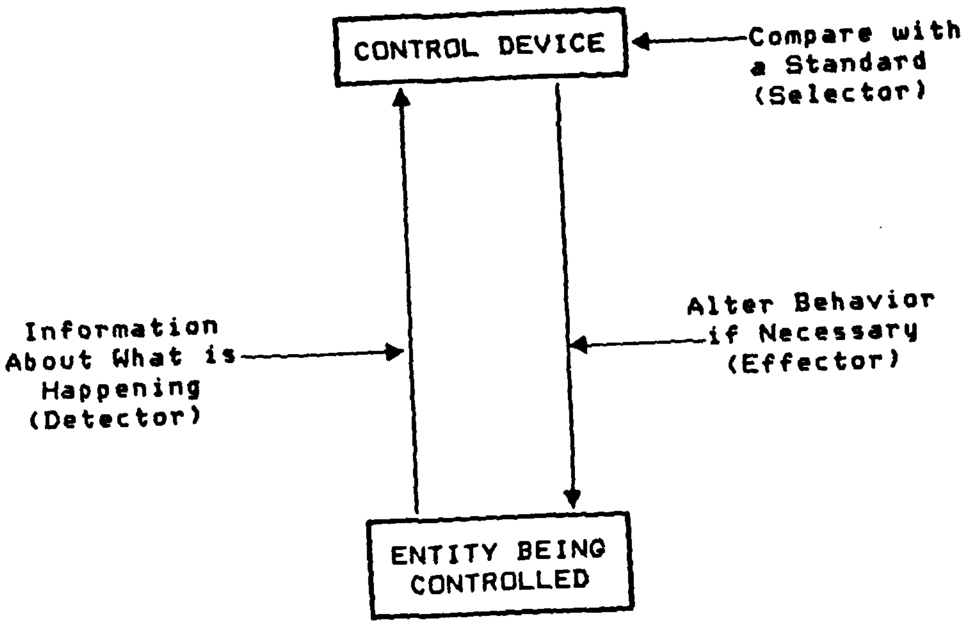
Johnson, Monsen, Knowles, and Saxeberg also present a a model of a control system containing four elements; however, these differ from the model described above. The elements included in this model are the characteristic to

be controlled, a sensor, a comparator, and an activator (83). This is shown in Figure 4.

In this conceptualization, the particular system output characteristic or parameter of the system output to be controlled is considered an essential element. The sensor is a means or device to measure that characteristic or parameter. The third element, the comparator, evaluates the state of the system to be controlled by comparing the measurements provided by the sensor to preplanned objectives. The activator is capable of directing the corrective actions required to bring the outputs of the system back within desired limits.

In comparing these two models it is apparent that, with the exception of the communicator and characteristic to be controlled elements, the functions described are the same. The detector, selector, and effector in Figure 3 are equivalent to the sensor, comparator, and activator in Figure 4.

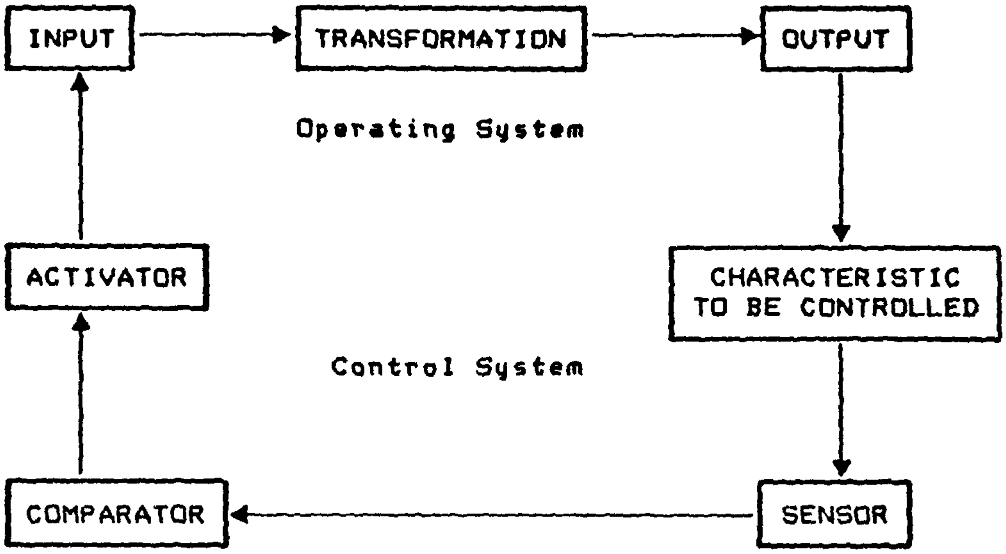
If the characteristic or parameter to be controlled is considered information and the purpose of the communicator is to transfer information among the other elements then it is not inappropriate to consider information as a key fifth element of a control system. In this view, the purpose of the sensor is to collect data and/or information and the purpose of the communicator and comparator is to process information. Within the



Adapted from Yang (82)

ELEMENTS OF A CONTROL SYSTEM

Figure 3



Adapted from Johnson Monsen Knowles and Saxeberg (84)

ELEMENTS OF A CONTROL SYSTEM

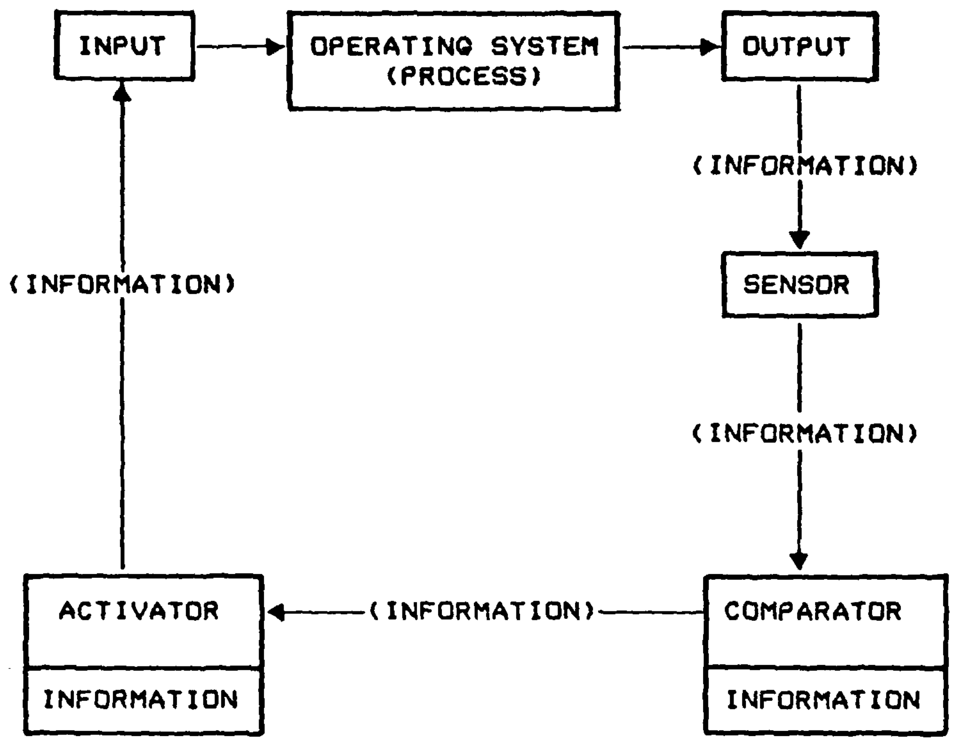
Figure 4

comparator is information concerning preset standards or limits and the decision rules to be followed in comparing information input from the sensor. In operation, this element makes a decision, which by previous definition requires information, concerning the status of the system being controlled.

The result of this decision is information which is then passed by the communicator to the activator. The activator transforms this input information into instructions (information) or direct action based on the direction and magnitude of the information received from the comparator, the type of system being controlled, and the decision rules (information) contained within the activator. These control instructions are then communicated as inputs to the operating system to bring it under control. This model is shown in Figure 5.

The idea that information is critical to control is reinforced by other authors. Johnson, Kast and Rosenzweig explain that information flowing through an information network establishes the basis for and is the medium of control. Information is the connecting link in any control process (85,86).

Weiner's definition of control as involving the sending of messages implies that information is a key component of control (87). He has also classified communication, which is the transfer of information, and control together since



INFORMATION BASED MODEL OF A CONTROL SYSTEM

Figure 5

control requires the transmission and receipt of messages. Russell Ackoff has proposed a similar connection in his statements that "information systems are subsystems of control systems" (88). He continues to explain that effective information systems cannot be developed without considering control and control concepts.

Control is required within the hospital system in order for it to operate effectively and efficiently (89,90). Control systems within an organization are composed of the same basic elements and perform the same functions as the models described above. In organizational control systems, the characteristics or conditions to be monitored are the objectives of the organization and the desired state to be achieved is the goal of the organization.

Control systems within organizations usually operate through people. The identification of deviation from desired objectives and the selection of appropriate courses of actions are made by managers in the form of decisions (91). Communication of information in manual systems is verbal and written in the form of letters, memos, instructions, guidelines, policies and records.

The Cost of Information Handling in Hospitals

In an observation and time measurement study of manual information handling and associated costs in three general

hospitals, Jydstrup et al found that preparation and communication of written information consumed 23.89% of total hospital operating costs. This figure was considered a minimum since educational activities and informal communication of information were not included (92).

In all three hospitals, nursing personnel were involved in the greatest amount of information handling. Nurses, nurses aides, and ward clerks averaged 34% of total work time spent in information activities. Other administrative areas had higher percentages per person spent in information preparation and exchange but in these areas fewer numbers of people were involved. These findings are supported by other authors who see the nursing unit as the focal point for all patient care related information within the hospital (93).

As part of a project to develop an evaluation plan for an automated medical data processing system for Kaiser Foundation hospitals, Richart collected baseline data from three hospitals operating with non-automated information systems. Manpower costs associated with information commerce and patient care related communication were established through observation of operations.

Total information handling cost in these facilities was reported as 35 to 39% of total hospital operating costs. One half of this figure was estimated to be manpower costs. This estimate was drawn from observations

that across all work groups in all three hospitals, 25 to 30% of total work time was spent in patient care related information activities. (94).

Need for Improved Communication in Hospitals

Feedback

Simborg in an observation study and analysis of a manual information system used in a 31 bed acute care medical ward determined that 15% of all physician's non-drug orders written in a two week period were not carried out. This figure was reported as a minimum since in many cases it was impossible for investigators to determine if an order was actually carried out (95).

Two areas accounted for 70% of those orders not completed. Those were communication errors (22%) and execution errors (58%). Communication errors were defined as those occuring during manual transcription of orders. To correct these problems, elimination of manual transcription was recommended.

Execution errors were defined as those for which orders were written, transcribed, and communicated correctly but were not carried out. Two of the major suggestions to correct these errors were to develop the capability to provide feedback to physicians concerning orders and to provide a single reference source to be reviewed to determine the status of orders (96).

On Site Data Collection

Several authors have recommended the need to collect data at its source in order to improve information accuracy, use and value. The source of the majority of patient related data and the point of use of a large portion of patient data is at the bedside (97-100). The objective of gathering and communicating data to the patient's bedside is to enable members of the health care team to share all available data immediately and have available all information needed to perform their jobs.

By entering data at its source into automated data processing systems, delays and errors induced by transcription and verbal communication can be avoided (101,102). Levy and Baskin have emphasized that source data input is critical to successful automated patient care systems (103). It follows then that if entry of data at its source to provide immediate availability of data and information is desirable, a means of rapidly communicating that information to its point of use is also desirable and required.

Collen has compared the data handling and communication within a hospital with the human nervous system. Neither can function without its transmission system. In this light he lists some of the prime objectives of a medical information system as communication between and among health care practitioners and medical records (104).

This idea is supported by others who have written that communication among providers is accomplished through the communication of shared information (105,106). The goal of a medical information system is to provide this shared information to the decision maker when and where it is needed. The key objective of the medical information system is then to provide rapid, accurate communication (107-111).

Communication is essential to the functioning of medical facilities. It is necessary to provide information for planning and decision making in both management and patient care areas and in the control of operations. If significant improvements in efficiency, effectiveness and productivity are to occur new methods, techniques and equipment are needed for data capture and information communication (112).

Cordless Telephones

An extensive computerized literature search was made. The terms wireless, radio, telephone, data communication and data transmission were used as keys for the search. Several pages of listings of articles in electronics, communication, mining, and transportation literature resulted. The vast majority of these dealt with technologies and applications with no identifiable relevance to this study. Only a few articles dealing with wireless or cordless telephones were identified. No

articles describing the use of cordless telephones to transmit computerized data were located. The location of applicable articles during manually conducted searches of a university library was hindered by the investigator's unfamiliarity with the literature of the disciplines involved.

Cordless telephones are relatively new arrivals in commercial markets; however they use as a message carrier frequency modulation (FM) radio transmission which has been in use for about 65 years. Because this is not new or state of the art technology it is speculated that it is overlooked or ignored by engineers and the literature of the disciplines concerned (113).

Narrow band FM transmission of data has proven to be an acceptable, effective mode of communication with error rates reported as low as one times 10 to the minus 9th bits transmitted (114-115). This low error rate is well above a design objective of one times 10 to the minus 5th bits used in many communications circuits (116). In communications networks using error checking routines and repeat transmission of questionable character strings, these error rates can be reduced to essentially zero.

The cordless telephone instrument consists of two separate devices; a radio transmitter/receiver base unit which is connected to the existing hardwired telephone system and a portable radio transmitter/receiver

handset. In use, the base station unit is connected to a 110-120 volt power supply and to the switched telephone network through connecting cords supplied. The portable cordless handset is self powered using rechargeable nickle-cadmium batteries built into the device. These are charged whenever the handset is stored on the receiver.

The transmitter/receiver, or transponder, located in the base unit is always "on" when the unit is connected to a power supply. When an incoming call is received, a 48 V ringing signal transmitted by the telephone company switching complex activates a frequency modulation (FM) transmitter in the base unit. This transmitter injects an FM radio signal back through the power supply cord into the electrical supply wiring system. The electrical supply wiring then becomes a large transmission antenna. From this antenna, the FM radio signal is radiated into the surrounding air space where it can be received by a ferrite bar antenna built into the receiver handset.

To receive a call at the portable handset, the on switch or talk button is pressed. This activates an FM transmitter within the handset. A signal transmission is made from the handset antenna through air space to a receiving antenna in the base unit. This transmission does not involve the electrical supply wiring system. When the base unit receives this incoming radio signal its circuitry completes the connection to the telephone

network and two way communication is established. Analog signals are transmitted and received between the two cordless telephone components via FM radio signals as above.

To make an outgoing call from the cordless handset, the sequence described is reversed. Activating the handset causes an FM signal to be transmitted to the base unit which establishes a connection with the switched telephone network. Numbered keys on the portable handset permit activation of a pulse dialer within the base unit and the call can be completed (117-121).

Two articles dealing with the propagation characteristics of mobile or cordless telephones discussed the influences on quality transmission and reception of FM signals. From these, some of the variables to be investigated in this study were identified. Other possible variables were identified from the manufacturer's operating instructions for the device used.

Tsujimura and Kuwabara in their description of a cordless telephone system operating in the 250 to 400 MHz band have stated that past studies were performed using high power long distance equipment with the transmitting antenna at great height above the ground. They propose that additional studies are required utilizing equipment designed for short distances using low power.

Influences on transmission quality and propagation identified include the type of building environment, wooden or steel and concrete, in which the transmissions are made, the height of the transmitting antenna above the ground, and the presence and location of metal office furniture. Other influences were distances between the transmitter and receiver and antenna polarization (the angle of the antenna from vertical) (122).

A second article describing the Bell System's Advanced Mobile Phone System (AMPS) equipment identified other possible influences on wave propagation and transmission quality. These included the transmission unit's antenna length, the presence of the operator's body, and reduced transmission power due to the small batteries required in portable units (123). Other possible influences are the presence of operating fluorescent lights, the use of shielded electrical conduction cable within the building in which transmissions are made, and the operation of other radio devices using the same frequencies (124-125).

III. PRE-TEST

Preliminary Testing

Pre-testing of equipment, programs, and study procedures was conducted on April 19 through 21, 1983. Transmissions were made from locations at varying distances and directions from the building in which the receiver base unit was located in order to try and determine the maximum effective transmission range. 'Loud static interferrence was audible at approximately 100 feet in all directions as the telephone handset was moved close to overhead power transmission lines or other campus buildings.

Transmission within the building in which the receiving unit was located was possible from a distance of 100 feet. This was selected as the maximum distance to be evaluated in this study. The selection of a maximum transmission distance of 100 feet limited the choice of the shorter distance to be used and the type of intervening wall and door to be included in the study. An existing inside concrete block and tile wall containing a wooden door was selected. A distance of 35 feet was selected as the shorter distance to be used since this allowed

transmissions to be made from a location outside of the wall and door. The intervening wall and door was considered to be present when the door was closed and absent when the door was open.

Several transmissions were then made from the 35 and 100 feet distances and from a hardwired standard telephone to test the applications programs used in the study. It was found that the data received from all transmissions included a blank first record. Investigation revealed that the MSI terminal used attached four non-displayed control characters and three terminal identification character strings to the beginning of each transmission.

The applications programs were changed to bypass the four non-displayed control characters and to incorporate the three terminal identification character strings. This resulted in the deletion of the first blank record and a total transmission of 303 character string records to be included in the control file and percentage of accuracy calculations.

Transmissions using the cordless telephone were made using a line tap to connect the base unit to a six button telephone/intercom system within the building. When the cordless telephone was in operation, other telephone users within the building were unaware that the line was in use since the indicator lights on their telephone instruments were not illuminated. It was decided to make

study transmissions in the early morning or on weekends when other telephone users were not in the building to avoid the possibility of errors being introduced by the interruption of transmissions by persons attempting to make outgoing telephone calls.

Pre-Test Data Collection

Twelve transmission scenarios were randomly selected from the one-half replication test matrix. These are listed in Table 6. Dependent variable values substituted for matrix entries during the pre-test are in Table 7. These 12 transmissions were made between 5 and 8 AM on April 21, 1983. Results of these pre-test transmissions are in Table 8.

Discussion

Several minor problems were encountered when collecting pre-test data. It was noted that since the nylon adapter plug necessary to connect the data entry terminal and the cordless telephone was not permanently attached, it could be easily dislodged or moved on the mouthpiece of the cordless telephone. This might induce extraneous noise and error. Care was taken to insure that when the telephone transmitter was used the adapter plug was not moved.

Another possible error inducing problem was static induced by movement of the instrument during transmission.

Table 6

PRE-TEST MATRIX

No.	X_0	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
9.	+1	+1	−1	−1	−1	+1	−1	−1	−1
13.	+1	−1	−1	−1	+1	+1	−1	−1	−1
16.	+1	−1	+1	+1	+1	+1	−1	−1	−1
21.	+1	−1	−1	−1	+1	−1	+1	−1	−1
22.	+1	+1	+1	−1	+1	−1	+1	−1	−1
41.	+1	−1	−1	−1	−1	+1	−1	+1	−1
64.	+1	−1	+1	+1	+1	+1	+1	+1	−1
68.	+1	+1	+1	+1	−1	1	−1	−1	+1
77.	+1	+1	−1	−1	+1	+1	−1	−1	+1
93.	+1	−1	−1	−1	+1	+1	+1	−1	+1
110.	+1	+1	+1	−1	+1	+1	−1	+1	+1
114.	+1	−1	+1	−1	−1	−1	+1	+1	+1

Table 7

VALUES ASSIGNED TO PRE-TEST MATRIX ENTRIES

Value Listed in Matrix		+1	-1
X_1	Distance	100 ft.	35 ft.
X_2	Height of Receiver	6 ft.	2 ft.
X_3	Wall/Door	Yes	No
X_4	Fluorescent Lights	Yes	No
X_5	Metal Cabinet	Yes	No
X_6	Antenna Length	0 in.	12 in.
X_7	Antenna Angle	Horizontal	Vertical
X_8	Human Body	Yes	No

Table 8

PRE-TEST RESULTS

Matrix Number	Number Records Rec'd	Number Records Correct	Number Record Errors Rec'd	Number Records Missed(-) Extra(+)	Percent Correct Records Rec'd
9.	302	283	19	-1	93.39
13.	303	303	0	0	100.00
16.	303	303	0	0	100.00
21.	303	303	0	0	100.00
22.	0	0	0	-303	0.00
41.	303	303	0	0	100.00
64.	301	296	5	-2	97.68
68.	307	302	1	+4 *	99.66
77.	302	300	2	-1	99.00
93.	302	301	1	-1	99.33
110.	303	303	0	0	100.00
114.	303	303	0	0	100.00

* Extra records received represent noise not included in original transmission records. These were not included in computation of accuracy percentages.

In each transmission, and during later study transmissions, the cordless telephone transmitter was held as still as possible with the face of the instrument perpendicular to a direct line between the transmitter and receiver.

It was extremely difficult to establish the initial telephone connection to the computer system when trying to transmit from the long distance (100 ft.) while the antenna was in the closed position (0 in.). To overcome this difficulty, the telephone handset antenna was extended to full length and the telephone connection was established. The antenna was then completely closed and the transmission made. This procedure was followed in all other similar transmissions.

Failure of transmission scenario number 22 to result in a completed data file highlighted the importance of accurate log keeping for proper identification of data files with the transmissions which input those data files. The start and stop times of each data transmission were noted on a worksheet at the transmission site. The stop time proved to be the most useful in identifying correct data files since the file creation time maintained by the computer system was established as, or very shortly after, each transmission was completed.

Data obtained from the pre-test were not statistically analyzed. Matching character strings were displayed on a computer terminal and errors received were printed for

review. In addition, computer output reports were studied and compared to applications programs to insure they correctly represented the pre-test results. In the judgement of the investigator, results and programs were accurate and appropriate.

IV. METHODOLOGY

Purpose of the Study

This was an exploratory study performed to identify some of the variables associated with the transmission of computerized data using a commercially available voice grade cordless telephone as a part of a telecommunications link between a portable data entry terminal and a host computer. The population to which the results of this study should be generalizeable consists of all cordless telephones using a similar technology for transmission which are compatible with the switched telephone network existing in the United States.

Variables Included in the Study

Independent Variables

A review of the literature concerning data transmission and cordless telephones, and discussions with personnel working in data communications had indicated several possible variables for investigation (127-130). These are listed in Table 9.

Of these initially identified variables, numbers 1 through 8 were investigated in this study. The possible

variable of the presence of other devices transmitting on the same or closely spaced radio frequencies was not studied due to the unavailability of the necessary transmitting and measuring devices. The variable of the presence of shielded electrical cable was not investigated since it was not available in the area in which the investigation was conducted.

The Dependent Variable

The dependent variable in the study was the accuracy of data transmitted using the cordless telephone and received by tha host computer. A percentage of 13 character number string records transmitted from the MSI Portable Data Terminal to the host computer which matched a control file of records previously stored in the computer was chosen as a measure of transmission accuracy. This choice was based on the difficulty of programming necessary to determine the accuracy of individual bits or bytes.

Experimental Design

The experimental design used in this study was a screening fractional factorial design as described by Mendenhall. Two one-quarter replications were used (131). Values assigned to each variable are listed in Table 10.

To develop the replications tested, a matrix of all 256 possible combinations of eight variables with two values

Table 9

VARIABLES FOR INITIAL INVESTIGATION

1. DISTANCE FROM TRANSMITTER TO RECEIVER
2. HEIGHT OF RECEIVER BASE ABOVE THE FLOOR
3. INTERVENING WALLS BETWEEN TRANSMITTER AND RECEIVER
4. PRESENCE OF OPERATING FLUORESCENT LIGHTS
5. INTERVENING METAL FURNITURE/ CABINETS BETWEEN TRANSMITTER AND RECEIVER
6. LENGTH OF TRANSMITTER ANTENNA
7. ANGLE OF THE TRANSMITTING ANTENNA FROM VERTICAL
8. HUMAN BODY BETWEEN TRANSMITTER AND RECEIVER
9. USE OF SHIELDED ELECTRICAL CABLE IN FACILITY ELECTRICAL WIRING
10. RADIO INTERFERENCE FROM OTHER DEVICES TRANSMITTING ON SAME FREQUENCY

Table 10

VALUES ASSIGNED TO MATRIX ENTRIES

Value listed in matrix		+	-
X(1)	Distance	100 ft	35 ft
X(2)	Height of Receiver	6 ft	2 ft
X(3)	Wall/Door	Yes	No
X(4)	Fluorescent Lights	Yes	No
X(5)	Metal Cabinet	Yes	No
X(6)	Antenna Length	0 in	12 in
X(7)	Antenna Angle	Horizontal	Vertical
X(8)	Human Body	Yes	No

per variable was drawn. A defining contrast to be used to select the one-half replication to be used in the study was based on the algebraic value of eight way interactions resulting from expansion of the matrix. To compute this, the algebraic product of the eight variable values in each row in the matrix was calculated. From these results, the 128 combinations with a positive product were selected. The algebraic products of a four way interactions calcuated by multiplying the values of the first four variables listed in the matrix vector were then used as a defining contrast to identify the one-quarter replication subsets used during test transmissions. Those four way interactions resulting in a positive product were grouped into one-quarter replication A and those with negative products into one-quarter replication B. Copies of the replication matrices are at Appendix A.

Using the values listed in Table 10, 128 separate transmissions could then be made. For example, a typical row was as follows:

X(1)	X(2)	X(3)	X(4)	X(5)	X(6)	X(7)	X(8)
-1	-1	-1	+1	+1	-1	-1	-1

This represents a transmission to be made:

From a distance of 35 feet.

With the base unit two feet above the floor

With no intervening wall and door.

With fluorescent lights on.

With an intervening metal cabinet.

With the transmitting antenna fully extended.

With the transmitting antenna vertical.

With no intervening human body.

Operational Definitions

The values selected for use in this screening experiment were chosen based on the judgement of the investigator and a consulting statistician and limitations in the environment in which the study was performed. Distances selected were based on the maximum distance possible without static interferrence from outside power transmission lines (100 ft.) and a shorter distance outside of the intervening wall and door (35 ft.). Heights of the base unit above the ground floor of two and six feet were chosen to represent an average expected table height and the maximum height the unit could be installed with fully extended antenna in an average room.

Antenna lengths of zero and 12 inches were chosen to represent completely closed and fully extended conditions. Polarization angles of zero degrees (vertical) and 90 degrees (horizontal) were chosen to represent maximum differences. Other values represent dichotomous situations involving the presence or absence of obstructions or of operating fluorescent lights which may have produced electromagnetic interferrence.

The presence of an intervening wall and door between the transmitter and receiver was operationally defined as a concrete block and tile inside building wall with a closed 36" wooden door located 30 feet from the receiver. The absence of an intervening wall and door was operationally defined as a concrete block and tile inside building wall with the 36" wooden door opened.

The presence of an intervening metal cabinet was operationally defined as the location between the transmitter and receiver of a metal unit dose medication cart at a distance of two feet from the transmitter. The presence of fluorescent lights was operationally defined as all lighting between the transmitter and receiver being on and illuminated. A floor plan showing the telephone components and lighting fixtures and a lighting fixture specification list is at Appendix B. The presence of a human body was operationally defined as the investigator being located between the transmitter and receiver with the transmitter held six inches from the body.

The percentage of accurate transmission was operationally defined as the number of correctly matched pairs of records (N) divided by 303, the total number of record strings contained in the file (N/303 X 100 = % accuracy). A total count of 303 records resulted from the addition of a three record identification sequence to the beginning of each transmission by the MSI terminal.

The Linear Model

The linear model used in this experimental design was as follows:

$$Y = B_0 + B_1 X_1 + B_2 X_2 + B_3 X_3 \ldots + B_8 X_8 \qquad \text{(Main Effects)}$$

$$+ B_9 X_1 X_2 \ldots + B_{36} X_7 X_8 \qquad \text{(2 Way Interactions)}$$

$$+ B_{37} X_1 X_2 X_3 \ldots + B_{92} X_6 X_7 X_8 \qquad \text{(3 Way Interactions)}$$

$$+ B_{93} X_1 X_2 X_3 X_4 \ldots + B_{162} X_5 X_6 X_7 X_8 \qquad \text{(4 Way Interactions)}$$

$$+ B_{163} X_1 X_2 X_3 X_4 X_5 \ldots + B_{218} X_4 X_5 X_6 X_7 X_8 \qquad \text{(5 Way Interactions)}$$

$$+ B_{219} X_1 X_2 X_3 X_4 X_5 X_6 \ldots \qquad \text{(6 Way Interactions)}$$

$$+ B_{247} X_1 X_2 X_3 X_4 X_5 X_6 X_7 \ldots \qquad \text{(7 Way Interactions)}$$

$$+ B_{256} X_1 X_2 X_3 X_4 X_5 X_6 X_7 X_8 \qquad \text{(8 Way Interaction)}$$

$$+ E \qquad \text{(Error)}$$

where:

Y = dependent variable (% accurate transmission).

B_0 = intercept.

B_i = the effect of independent variable(s).

X_i = the independent variable(s).

E = random error.

Equipment Used

The sample telephone device selected for study was a convenience sample based on easy availability and relatively low cost. It was purchased through a local franchised Radio Shack dealer and was a standard shelf stock item provided by that corporation. Purchase price for the instrument was approximately $200.

The instrument used in the study was a Radio Shack brand DUoFone ET-330, model number 43-267B, serial number 021032 manufactured in February 1982. The FCC identification number assigned to this device was AA094043-267B.

In order to transmit data through any data communications link, data entry or storage and transmitting devices are required. For this study, an MSI/66 Portable Data Terminal was used. The specific device used, serial number 593082, part number 26080-12-06, manufactured by MSI Data Corporation, consisted of a data entry key pad, special command function keys, a display screen capable of displaying 12 characters, and a storage memory with a capacity of 661 twelve character entries. It also contained an integral transmitting capability.

As each entry stored in the terminal's memory was transmitted, a delimiting character (+) was attached to the

end of each character string. This delimiting character was used to indicate the end of one entry and the beginning of the next. This enabled the receiving computer software to recognize completed records and allowed recognition of variable length records if required.

An accoustic coupler modulation-demodulation (modem) module could be attached to transform digital data signals into audible analog signals for transmission over telephone lines. The accoustic coupler modem used in this study was MSI model number 77-400, part number 23314-00-00 REV E, serial number 157199. This device was compatible with Bell 103/113 equipment.

To transmit data, the modem module was attached to the terminal using a male-female mated plug integral to the components. Upon command, the contents of the storage memory within the MSI/66 terminal were converted into analog signals and transmitted in sequential order through a standard accoustic coupler connection to the telephone handset. Transmission was in a simplex mode accepting no response from the host computer.

In order to accept and transmit data through the accoustic coupler modem module, the MSI terminal had to be parameterized. This process specified the transmission rate and parity to be used, specified the maximum length of each entry allowed, identified the use

and position of check digits, and allowed or disallowed the use of a light pen bar code wand reader attachment.

The terminal used in the study was parameterized using the code number 2120000 (125). This specified the following:

Baud rate 300.

Maximum entry size 12 characters.

Parity even, TTY compatible.

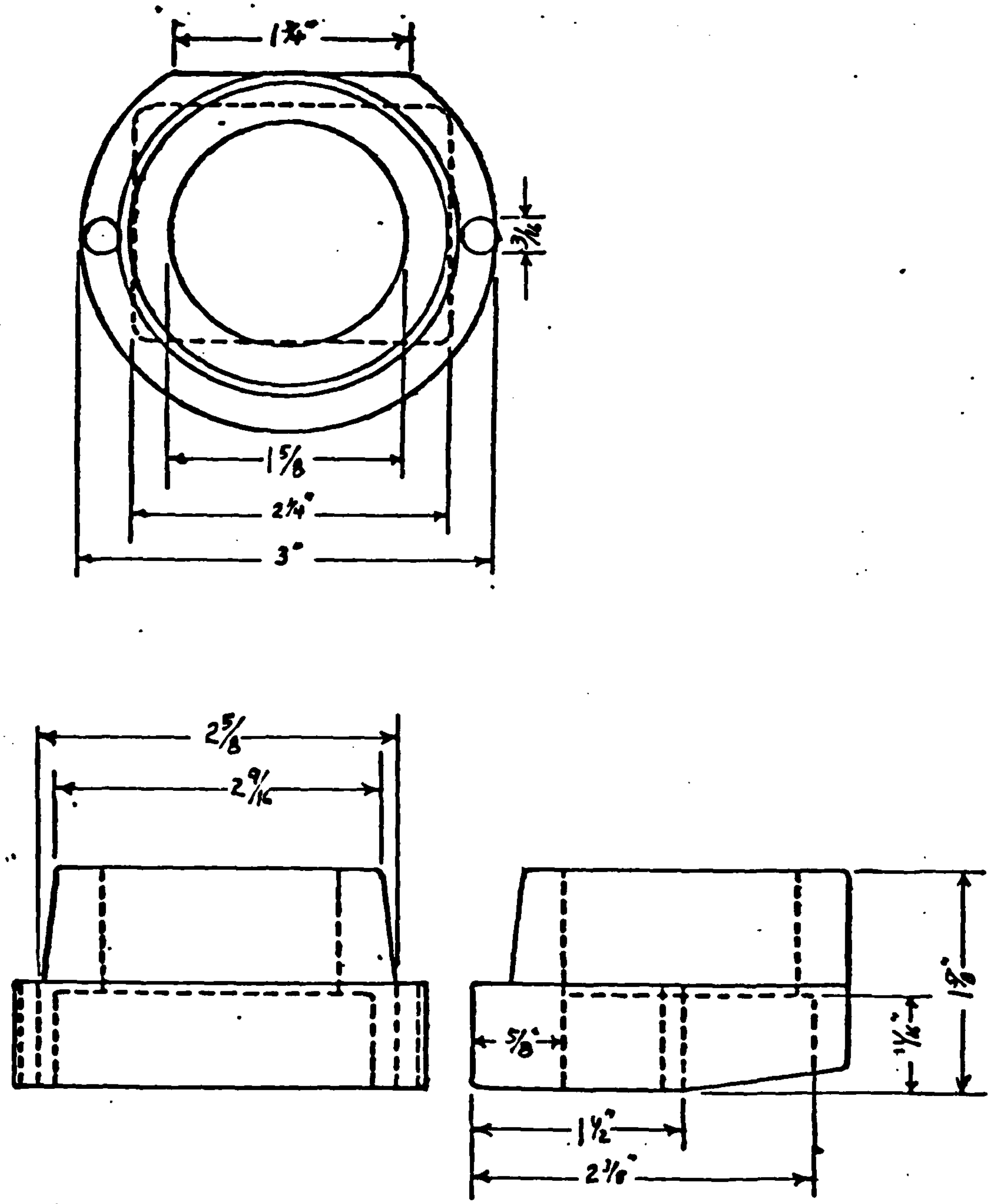
No check digits used.

Wand reader expanded version E1 allowed.

To enable the cordless telephone handset to be connected to the accoustic coupler modem, a hard nylon male adapter plug was manufactured. This connector was made to resemble the mouthpiece of a standard hardwired telephone which the accoustic coupler was designed to accept. A line drawing with dimensions of the adapter is at figure 6.

At the receiving end of the transmission, another modem device was connected to the telephone line. This device received the incoming analog signals and converted them back into digital signals for acceptance by the host computer. In operation it was connected to a universal line multiplexer (ULM) port on a Data General NOVA 4X minicomputer using the connection pin configuration shown in Table 11.

The modem used in this study was a Hayes Stack Smartmodem manufactured by Hayes Microcomputer Products,



MALE ADAPTER PLUG

Figure 6

Table 11

MODEM - ULM CONNECTOR PIN CONFIGURATION

MODEM PIN CONNECTOR		ULM CONNECTOR	
EIA SIGNAL	PIN NUMBER	PIN NUMBER	ULM SIGNAL
PROTECTIVE GROUND	1	9	PROTECTIVE GROUND
TRANSMIT DATA	2	2	TRANSMIT DATA
RECEIVE DATA	3	11	RECEIVE DATA
REQUEST TO SEND	4	12	REQUEST TO SEND
CLEAR TO SEND	5	6	CLEAR TO SEND
DATA SET READY	6	7	DATA SET READY
SIGNAL GROUND	7	9	SIGNAL GROUND
CARRIER DETECT	8	4	CARRIER DETECT
DATA TERMINAL READY	20	5	DATA TERMINAL READY
RING	22	3	RING

Inc., Norcross, Georgia. This was a Bell-103 type modem. The particular device used was identified by an FCC registration number BFJ9D9-68737-DME, serial number 161D94773, and FCC identification number BFJ9D9-08-0090.

The host computer used to receive incoming transmissions and process the data received was a 256 kilo-byte minicomuter with 20 megabytes of disk storage. It was identified by the manufacturer, the Data General Corporation of Westboro, Massachusetts as model number 8395-N, serial number 16689-4. Programs to accept and process transmitted data and prepare output results reports were written in Data General Business Basic.

Data Preparation and Processing

In preparation for the study, a series of 300 twelve digit random numbers selected from random number tables were entered into the MSI/66 terminal. The selection of 300 character string records for transmission was based on the input buffer size of the host computer. To avoid the possibility of lost data caused by exceeding the capacity of the buffer, a transmission smaller than the maximum capacity was chosen. In addition, when study transmissions were made, no other users were allowed to input data. This was a hardware limitation caused by the use of a transmission device operating only in the simplex mode.

To measure the percentage of accuracy of transmission, a control file of 300 records, each containing one 13 character field, was entered into the host computer. This was accomplished by transmitting the random number file in the memory of the MSI terminal over a conventional hardwired telephone handset into the computer. These data were transmitted twice and stored in two separate files.

A set of computer programs was written using the Data General Business Basic Language to compare two data files consisting of 13 character records. In operation these programs sort one data file, labeled as the control file, into ascending numerical order and using a binary search algorithm search it for each record contained in the second file. A count of the total number of records received in each transmission was kept by the applications program along with a count of the number and percentage of correctly matched records in the two files. In establishing the control file to be used in the study, the transmission and matching process was repeated until a 100% accuracy figure was obtained on six separate transmissions.

Data Collection

At the start of each day's data collection involving the transmission of data, an inspection of the contents of the file names assigned by the computer system to previous

transmissions was made to determine the last consecutive file number assigned by the system. In addition, the investigator's chronograph was compared to the real time clock operating in the computer and synchronized. A log of transmission start and stop times, the consecutive transmission number, and the variables being manipulated for that transmission were maintained manually for each transmission made. As a double check, this manual log was compared to similar information maintained by the computer system at the end of each day's activities. Matching the time of file creation in the computer with the end of transmission time allowed correct identification of each test file with the transmission which created that test file. This procedure also allowed the identification of those transmissions which were made but for which a data file was not received.

Data for one-quarter replication A were collected on Sunday, April 24, 1983 between 5 A.M. and 6:30 P.M. Data for one-quarter replication B was collected on Saturday, April 30, 1983 between 4 A.M. and 5:30 P. M.

For each transmission, the variables listed in the matrix were set to the appropriate value. These were then double checked for accuracy and the telephone connection with the computer was established. At this point, the time was noted on the transmission log and the send key on the

data terminal was pressed. During all transmissions, the telephone handset transmitter was hand held by the investigator at a height of approximately 34 inches from the floor.

At the end of each transmission, the MSI terminal emitted an audible signal indicating that transmission was complete. At this time, the disconnect button on the telephone handset was pressed and the telephone connection with the host computer was severed. The end of transmission time was then noted on the transmission log.

After completion of all transmissions, a listing of files created arranged according to creation time was obtained from the host computer. This listing was compared to the manual transmission log to match the computerized files with the correct transmission scenario. If a file's creation time was the same as or within one minute after the end of transmission time on the manual log it was considered to be the result of that transmission. If the file creation time was between a transmission start and stop time on the manual log, it was considered to be the result of that transmission.

After each computerized data file was matched with the appropriate transmission, it was copied into 13 byte records in another file named to correspond with the matrix number representing that transmission. The program named Copy was used to rewrite and rename these

files. Results from the data collected were obtained by processing these numbered files using a program named Compare.

This program read each transmission file and searched the control file to determine if each record received in a transmission could be matched with an existing control record. From this search, an output report containing the number of correctly received records, the number of errors received, the number of records not received, the number of extra records received, and the percentage of accuracy for each transmission was produced. Copies of these applications programs will be available upon request.

V. RESULTS AND ANALYSIS OF DATA

Results

The total number of correct character strings received and the percentage of accurate transmissions received during each transmission were produced by the computer system. These results are in Appendix C.

Analysis

Derivation of the coefficients for the linear model described in Chapter III of this paper and statistical analysis of experimental results were performed on an IBM Model 3032 computer using Fortran programs developed by a consulting statistician (132-133). These programs expanded the initial study matrix to a 128 by 256 matrix and computed the estimated coefficients for each individual independent variable and all possible interactions of independent variables in the linear equation model.

For each estimated coefficient computed, the system next tested, using the z-test, the hypothesis that each coefficient was equal to zero or the alternative, that it was not equal to zero. This was done to determine if the independent variable or interaction of the variables

associated with that coefficient contributed significantly to the dependent variable Y. These statistical hypotheses are expressed in the following equations:

$$H_0 : B_i = 0$$

vs

$$H_A : B_i <> 0$$

The four way interaction used to divide the one-half replication matrix into two one-quarter replications was tested to determine the significance of this defining contrast. The z statistic for this interaction was not significant indicating that results from the two one-quarter replicates were not significantly confounded by time and could be combined in the analysis.

Since a one-half replication of all possible combinations of variables was used in the study, the linear model to be derived was limited to 128 factors and degrees of freedom. In this model, estimates of the main effects are aliased with seven way interactions, two way interactions with six way interactions, three way interactions with five way interactions, and four way interactions with other four way interactions.

For example, an estimate of the beta coefficient for the interaction of the first three variables would be confounded with and have the same numeric value as the estimated beta for the interaction of the remaining five

variables. In developing the study model therefore, the assumption was made that the main effects, two way and three way interactions were most significant and higher order interactions would be included as error. This model consisted of a linear equation with 93 factors, the intercept, and 92 main effects and interactions, and error. This left 35 degrees of freedom for use in the statistical analysis. The X variables involved in each factor, the estimated beta coefficient, the z-test statistic, and the statistical significance of each of these factors are at Appendix D.

A complete linear model consisting of the intercept, the main effects, the two way, and the three way interactions was then constructed. This model consisted of the following 94 factors;

$$Y = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 \ldots + b_8 X_8 \qquad \text{(Main Effects)}$$

$$+ b_9 X_1 X_2 \ldots + b_{36} X_7 X_8 \qquad \text{(2 Way Interactions)}$$

$$+ b_{37} X_1 X_2 X_3 \ldots + b_{92} X_6 X_7 X_8 \qquad \text{(3 Way Interactions)}$$

$$+ E \qquad \text{(Error)}$$

The sample coefficient of determination (R squared) for the complete model was computed to determine what portion of the value of Y was explained by the model. For this model the R squared was 0.988. This indicated that 98.8% of the total sum of squares was due to the model. The remaining 1.2% of the total sum of squares was

attributed to noise or random error (134-136). The correlation coefficient (r) for the model was computed as 0.997. This indicated a high degree of correlation between the values of X and the dependent variable Y. The standard deviation (S) for the complete model was 18.51

Computed z statistics from Appendix C indicated that 12 of the first 92 factors were significant at the 0.1 level. Inspection of the next 34 factors revealed that three of the four way interactions were also statistically significant.

A reduced linear model containing the intercept, the 15 statistically significant factors, and error was constructed as follows;

$$Y = b_0 + b_1 X_1 + b_6 X_6 + b_{13} X_1 X_6 + b_{20} X_2 X_7 + b_{21} X_2 X_8 +$$

$$b_{36} X_7 X_8 + b_{41} X_1 X_2 X_7 + b_{42} X_1 X_2 X_8 + b_{57} X_1 X_7 X_8 +$$

$$b_{70} X_2 X_6 X_7 + b_{71} X_2 X_6 X_8 + b_{92} X_6 X_7 X_8 + b_{105} X_1 X_2 X_6 X_7 +$$

$$b_{106} X_1 X_2 X_6 X_8 + b_{127} X_1 X_6 X_7 X_8 + \text{Error}$$

The sample coefficient of determination (R squared) for the reduced model was computed to determine what portion of the value of the dependent variable Y explained by this model. For this model, the R squared was 0.984. This indicated that 98.4% of the total sum of squares could be explained by the model. The correlation coefficient (r) for the model was 0.992. This indicated a

high correlation between the values of the independent variables X and interactions included in the model and the dependent variable Y. The standard deviation (S) for the reduced model was computed as 11.99.

Predicted Values

Estimates or predictions of transmission data accuracy can be made using the linear equations developed above. As a part of the analysis, the statistical programs developed predictions of accuracy values using the complete model. These predicted accuracy values for scenarios involving the main effects, two way, and three way interactions are at Appendix E.

Prediction of the accuracy of data transmission under stipulated conditions can also be made using the reduced model and calculated beta coefficients. For examples the following six scenarios are offered. For each the experimental Y value obtained during the study is listed and a predicted value calculated using the reduced linear model is given. These scenarios are taken from the experimental matrix. A 95% bound on the error for these estimates is plus or minus 23.51 in all cases.

Caluclations for obtaining these estimates used the beta coefficients listed in Appendix C. A matrix of the X values used to determine the algebraic product values of the interactions is at Table 13.

Table 12

Prediction Matrix

Scenario		1	2	3	4	5	6
X_1	Distance	−1	−1	+1	+1	+1	+1
X_2	Receiver Height	−1	−1	+1	+1	−1	+1
X_3	Wall	−1	−1	+1	−1	−1	+1
X_4	Lights	−1	−1	+1	−1	+1	−1
X_5	Cabinet	−1	+1	+1	−1	−1	−1
X_6	Antenna Length	−1	−1	−1	+1	+1	+1
X_7	Antenna Angle	−1	+1	−1	+1	−1	−1
X_8	Body	−1	−1	−1	−1	+1	+1

1. Transmission distance was 35 feet with the receiver on a work table. The transmitter was vertical with the transmitting antenna fully extended. There were no intervening obstructions and fluorescent lights were off. In this case, the test accuracy rate was 100% while the reduced model predicted 93.46%.

2. Transmission was from a short distance, 35 feet, with the receiver on a work table. The transmitter was

Table 12

PREDICTION MATRIX

Scenario		1	2	3	4	5	6
X_1	Distance	-1	-1	+1	+1	+1	+1
X_2	Receiver Height	-1	-1	+1	+1	-1	+1
X_3	Wall	-1	-1	+1	-1	-1	+1
X_4	Lights	-1	-1	+1	-1	+1	-1
X_5	Cabinet	-1	+1	+1	-1	-1	-1
X_6	Antenna Length	-1	-1	-1	+1	+1	+1
X_7	Antenna Angle	-1	+1	-1	+1	-1	-1
X_8	Body	-1	-1	-1	-1	+1	+1

1. Transmission distance was 35 feet with the receiver on a work table. The transmitter was verticsl with the transmitting antenna fully extended. There were no intervening obstructions and fluorescent lights were off. In this case, the test accuracy rate was 100% while the reduced model predicted 93.46%.

2. Transmission was from a short distance, 35 feet, with the receiver on a work table. The transmitter was

horizontal with the antenna fully extended and there was a metal cabinet between the transmitter and receiver. Fluorescent lights were off. In this scenario the actual accuracy rate received was 100% while the model predicted 106.16.

3. Transmission was from a long distance, 100 feet, with the receiver mounted at a height of six feet above the floor. The transmitter was vertical with the antenna fully extended. There was a metal cabinet and an intervening wall between the transmitter and receiver. Fluorescent lights were on. Under these conditions the linear model predicted an accuracy rate of 106.04% while an actual value of 94.38% was obtained.

4. Transmission was from a distance of 100 feet with the receiver mounted six feet above the floor. The transmitter was horizontal with the antenna fully closed. There were no obstructions and fluorescent lights were off. Under these conditions the model predicted an accuracy rate of 23.74% while an actual rate of 34.98% was obtained.

5. Transmission was made from a distance of 100 feet with the receiver on a work table. Fluorescent lights were on and there was an intervening human body between the transmitter and receiver. The transmitter was vertical and the antenna was not extended. In this case, the model predicted a 23.74% accuracy rate while the actual value obtained was 3.30%.

6. Transmission was made from a distance of 100 feet with the receiver mounted six feet above the floor. There was an intervening wall and cabinet between the transmitter and receiver. Fluorescent lights were off. The transmitter was vertical with the antenna closed. There was an intervening body located between the transmitter and receiver. Under these conditions, the model predicted 13.74% accuracy while 0% was obtained.

VI. SUMMARY

Discussion

The purpose of a this exploratory screening experiment was to identify some of the variables and interactions of variables which influence the accuracy of data transmitted over a communications link using a cordless telephone. Analysis of the study results identified 15 factors which appeared to have significantly influenced the accuracy of data received in the study.

These results indicated that the transmission of data using a cordless telephone is feasible. Further studies are required to define the limits of the use of these devices.

Follow on studies should consider the variables which this study suggests are significant as well as others not included in this study. Additional studies will also be required in hospitals which have a much more complex electromagnetic environment than the location in which this study was conducted.

Limitations

More accurate estimations of the beta coefficients in the linear models and of the significance of the factors involved in the statistical analysis of the study data can be made only if additional complete replications of all possible combinations are made. The experimental design used in this study resulted in confounding of the estimates for higher level interactions with estimates for the main effects and lower level interactions. These can be separately identified and improved estimates made if the entire full replication is tested.

Other possible limitations may be due to the equipment used. The cordless telephone receiver unit was connected through a line tap into a five button telephone system. It is possible that a direct connection into a single line may have resulted in some change in the study results.

Implications

The use of cordless telephones may provide a useful low cost alternative for the transmission of computerized data. The use of these instruments could prove to be highly beneficial in hospitals and other areas engaged in high volume information commerce. This study is a first step in determining the feasibility and usefulness of this technology.

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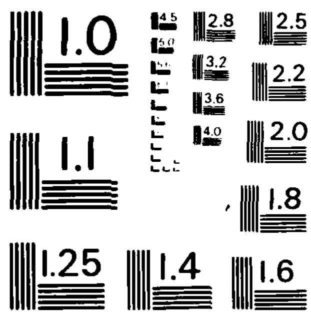

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APPENDICES

APPENDIX A

REPLICATION MATRICES

ONE-HALF REPLICATION MATRIX

No.	X_0	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
1.	+1	-1	-1	-1	-1	-1	-1	-1	-1
2.	+1	+1	+1	-1	-1	-1	-1	-1	-1
3.	+1	+1	-1	+1	-1	-1	-1	-1	-1
4.	+1	-1	+1	+1	-1	-1	-1	-1	-1
5.	+1	+1	-1	-1	+1	-1	-1	-1	-1
6.	+1	-1	+1	-1	+1	-1	-1	-1	-1
7.	+1	-1	-1	+1	+1	-1	-1	-1	-1
8.	+1	+1	+1	+1	+1	-1	-1	-1	-1
9.	+1	+1	-1	-1	-1	+1	-1	-1	-1
10.	+1	-1	+1	-1	-1	+1	-1	-1	-1
11.	+1	-1	-1	+1	-1	+1	-1	-1	-1
12.	+1	+1	+1	+1	-1	+1	-1	-1	-1
13.	+1	-1	-1	-1	+1	+1	-1	-1	-1
14.	+1	+1	+1	-1	+1	+1	-1	-1	-1
15.	+1	+1	-1	+1	+1	+1	-1	-1	-1
16.	+1	-1	+1	+1	+1	+1	-1	-1	-1
17.	+1	+1	-1	-1	-1	-1	+1	-1	-1
18.	+1	-1	+1	-1	-1	-1	+1	-1	-1
19.	+1	-1	-1	+1	-1	-1	+1	-1	-1
20.	+1	+1	+1	+1	-1	-1	+1	-1	-1
21.	+1	-1	-1	-1	+1	-1	+1	-1	-1
22.	+1	+1	+1	-1	+1	-1	+1	-1	-1

23.	+1	+1	−1	+1	+1	−1	+1	−1	−1
24.	+1	−1	+1	+1	+1	−1	+1	−1	−1
25.	+1	−1	−1	−1	−1	+1	+1	−1	−1
26.	+1	+1	+1	−1	−1	+1	+1	−1	−1
27.	+1	+1	−1	+1	−1	+1	+1	−1	−1
28.	+1	−1	+1	+1	−1	+1	+1	−1	−1
29.	+1	+1	−1	−1	+1	+1	+1	−1	−1
30.	+1	−1	+1	−1	+1	+1	+1	−1	−1
31.	+1	−1	−1	+1	+1	+1	+1	−1	−1
32.	+1	+1	+1	+1	+1	+1	+1	−1	−1
33.	+1	+1	−1	−1	−1	−1	−1	+1	−1
34.	+1	−1	+1	−1	−1	−1	−1	+1	−1
35.	+1	−1	−1	+1	−1	−1	−1	+1	−1
36.	+1	+1	+1	+1	−1	−1	−1	+1	−1
37.	+1	−1	−1	−1	+1	−1	−1	+1	−1
38.	+1	+1	+1	−1	+1	−1	−1	+1	−1
39.	+1	+1	−1	+1	+1	−1	−1	+1	−1
40.	+1	−1	+1	+1	+1	−1	−1	+1	−1
41.	+1	−1	−1	−1	−1	+1	−1	+1	−1
42.	+1	+1	+1	−1	−1	+1	−1	+1	−1
43.	+1	+1	−1	+1	−1	+1	−1	+1	−1
44.	+1	−1	+1	+1	−1	+1	−1	+1	−1
45.	+1	+1	−1	−1	+1	+1	−1	+1	−1
46.	+1	−1	+1	−1	+1	+1	−1	+1	−1
47.	+1	−1	−1	+1	+1	+1	−1	+1	−1
48.	+1	+1	+1	+1	+1	+1	−1	+1	−1

49.	+1	−1	−1	−1	−1	−1	+1	+1	−1
50.	+1	+1	+1	−1	−1	−1	+1	+1	−1
51.	+1	+1	−1	+1	−1	−1	+1	+1	−1
52.	+1	−1	+1	+1	−1	−1	+1	+1	−1
53.	+1	+1	−1	−1	+1	−1	+1	+1	−1
54.	+1	−1	+1	−1	+1	−1	+1	+1	−1
55.	+1	−1	−1	+1	+1	−1	+1	+1	−1
56.	+1	+1	+1	+1	+1	−1	+1	+1	−1
57.	+1	+1	−1	−1	−1	+1	+1	+1	−1
58.	+1	−1	+1	−1	−1	+1	+1	+1	−1
59.	+1	−1	−1	+1	−1	+1	+1	+1	−1
60.	+1	+1	+1	+1	−1	+1	+1	+1	−1
61.	+1	−1	−1	−1	+1	+1	+1	+1	−1
62.	+1	+1	+1	−1	+1	+1	+1	+1	−1
63.	+1	+1	−1	+1	+1	+1	+1	+1	−1
64.	+1	−1	+1	+1	+1	+1	+1	+1	−1
65.	+1	+1	−1	−1	−1	−1	−1	−1	+1
66.	+1	−1	+1	−1	−1	−1	−1	−1	+1
67.	+1	−1	−1	+1	−1	−1	−1	−1	+1
68.	+1	+1	+1	+1	−1	−1	−1	−1	+1
69.	+1	−1	−1	−1	+1	−1	−1	−1	+1
70.	+1	+1	+1	−1	+1	−1	−1	−1	+1
71.	+1	+1	−1	+1	+1	−1	−1	−1	+1
72.	+1	−1	+1	+1	+1	−1	−1	−1	+1
73.	+1	−1	−1	−1	−1	+1	−1	−1	+1
74.	+1	+1	+1	−1	−1	+1	−1	−1	+1

75.	+1	+1	−1	+1	−1	+1	−1	−1	+1
76.	+1	−1	+1	+1	−1	+1	−1	−1	+1
77.	+1	+1	−1	−1	+1	+1	−1	−1	+1
78.	+1	−1	+1	−1	+1	+1	−1	−1	+1
79.	+1	−1	−1	+1	+1	+1	−1	−1	+1
80.	+1	+1	+1	+1	+1	+1	−1	−1	+1
81.	+1	−1	−1	−1	−1	−1	+1	−1	+1
82.	+1	+1	+1	−1	−1	−1	+1	−1	+1
83.	+1	+1	−1	+1	−1	−1	+1	−1	+1
84.	+1	−1	+1	+1	−1	−1	+1	−1	+1
85.	+1	+1	−1	−1	+1	−1	+1	−1	+1
86.	+1	−1	+1	−1	+1	−1	+1	−1	+1
87.	+1	−1	−1	+1	+1	−1	+1	−1	+1
88.	+1	+1	+1	+1	+1	−1	+1	−1	+1
89.	+1	+1	−1	−1	−1	+1	+1	−1	+1
90.	+1	−1	+1	−1	−1	+1	+1	−1	+1
91.	+1	−1	−1	+1	−1	+1	+1	−1	+1
92.	+1	+1	+1	+1	−1	+1	+1	−1	+1
93.	+1	−1	−1	−1	+1	+1	+1	−1	+1
94.	+1	+1	+1	−1	+1	+1	+1	−1	+1
95.	+1	+1	−1	+1	+1	+1	+1	−1	+1
96.	+1	−1	+1	+1	+1	+1	+1	−1	+1
97.	+1	−1	−1	−1	−1	−1	−1	+1	+1
98.	+1	+1	+1	−1	−1	−1	−1	+1	+1
99.	+1	+1	−1	+1	−1	−1	−1	+1	+1
100.	+1	−1	+1	+1	−1	−1	−1	+1	+1

101.	+1	+1	−1	−1	+1	−1	−1	+1	+1
102.	+1	−1	+1	−1	+1	−1	−1	+1	+1
103.	+1	−1	−1	+1	+1	−1	−1	+1	+1
104.	+1	+1	+1	+1	+1	−1	−1	+1	+1
105.	+1	+1	−1	−1	−1	+1	−1	+1	+1
106.	+1	−1	+1	−1	−1	+1	−1	+1	+1
107.	+1	−1	−1	+1	−1	+1	−1	+1	+1
108.	+1	+1	+1	+1	−1	+1	−1	+1	+1
109.	+1	−1	−1	−1	+1	+1	−1	+1	+1
110.	+1	+1	+1	−1	+1	+1	−1	+1	+1
111.	+1	+1	−1	+1	+1	+1	−1	+1	+1
112.	+1	−1	+1	+1	+1	+1	−1	+1	+1
113.	+1	+1	−1	−1	−1	−1	+1	+1	+1
114.	+1	−1	+1	−1	−1	−1	+1	+1	+1
115.	+1	−1	−1	+1	−1	−1	+1	+1	+1
116.	+1	+1	+1	+1	−1	−1	+1	+1	+1
117.	+1	−1	−1	−1	+1	−1	+1	+1	+1
118.	+1	+1	+1	−1	+1	−1	+1	+1	+1
119.	+1	+1	−1	+1	+1	−1	+1	+1	+1
120.	+1	−1	+1	+1	+1	−1	+1	+1	+1
121.	+1	−1	−1	−1	−1	+1	+1	+1	+1
122.	+1	+1	+1	−1	−1	+1	+1	+1	+1
123.	+1	+1	−1	+1	−1	+1	+1	+1	+1
124.	+1	−1	+1	+1	−1	+1	+1	+1	+1
125.	+1	+1	−1	−1	+1	+1	+1	+1	+1
126.	+1	−1	+1	−1	+1	+1	+1	+1	+1

127.	+1	−1	−1	+1	+1	+1	+1	+1	+1
128.	+1	+1	+1	+1	+1	+1	+1	+1	+1

ONE-QUARTER REPLICATION A MATRIX

No.	X_0	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
1.	+1	-1	-1	-1	-1	-1	-1	-1	-1
2.	+1	+1	+1	-1	-1	-1	-1	-1	-1
3.	+1	+1	-1	+1	-1	-1	-1	-1	-1
4.	+1	-1	+1	+1	-1	-1	-1	-1	-1
5.	+1	+1	-1	-1	+1	-1	-1	-1	-1
6.	+1	-1	+1	-1	+1	-1	-1	-1	-1
7.	+1	-1	-1	+1	+1	-1	-1	-1	-1
8.	+1	+1	+1	+1	+1	-1	-1	-1	-1
25.	+1	-1	-1	-1	-1	+1	+1	-1	-1
26.	+1	+1	+1	-1	-1	+1	+1	-1	-1
27.	+1	+1	-1	+1	-1	+1	+1	-1	-1
28.	+1	-1	+1	+1	-1	+1	+1	-1	-1
29.	+1	+1	-1	-1	+1	+1	+1	-1	-1
30.	+1	-1	+1	-1	+1	+1	+1	-1	-1
31.	+1	-1	-1	+1	+1	+1	+1	-1	-1
32.	+1	+1	+1	+1	+1	+1	+1	-1	-1
41.	+1	-1	-1	-1	-1	+1	-1	+1	-1
42.	+1	+1	+1	-1	-1	+1	-1	+1	-1
43.	+1	+1	-1	+1	-1	+1	-1	+1	-1
44.	+1	-1	+1	+1	-1	+1	-1	+1	-1
45.	+1	+1	-1	-1	+1	+1	-1	+1	-1
46.	+1	-1	+1	-1	+1	+1	-1	+1	-1

47.	+1	−1	−1	+1	+1	+1	−1	+1	−1
48.	+1	+1	+1	+1	+1	+1	−1	+1	−1
49.	+1	−1	−1	−1	−1	−1	+1	+1	−1
50.	+1	+1	+1	−1	−1	−1	+1	+1	−1
51.	+1	+1	−1	+1	−1	−1	+1	+1	−1
52.	+1	−1	+1	+1	−1	−1	+1	+1	−1
53.	+1	+1	−1	−1	+1	−1	+1	+1	−1
54.	+1	−1	+1	−1	+1	−1	+1	+1	−1
55.	+1	−1	−1	+1	+1	−1	+1	+1	−1
56.	+1	+1	+1	+1	+1	−1	+1	+1	−1
73.	+1	−1	−1	−1	−1	+1	−1	−1	+1
74.	+1	+1	+1	−1	−1	+1	−1	−1	+1
75.	+1	+1	−1	+1	−1	+1	−1	−1	+1
76.	+1	−1	+1	+1	−1	+1	−1	−1	+1
77.	+1	+1	−1	−1	+1	+1	−1	−1	+1
78.	+1	−1	+1	−1	+1	+1	−1	−1	+1
79.	+1	−1	−1	+1	+1	+1	−1	−1	+1
80.	+1	+1	+1	+1	+1	+1	−1	−1	+1
81.	+1	−1	−1	−1	−1	−1	+1	−1	+1
82.	+1	+1	+1	−1	−1	−1	+1	−1	+1
83.	+1	+1	−1	+1	−1	−1	+1	−1	+1
84.	+1	−1	+1	+1	−1	−1	+1	−1	+1
85.	+1	+1	−1	−1	+1	−1	+1	−1	+1
86.	+1	−1	+1	−1	+1	−1	+1	−1	+1
87.	+1	−1	−1	+1	+1	−1	+1	−1	+1
88.	+1	+1	+1	+1	+1	−1	+1	−1	+1

97.	+1	−1	−1	−1	−1	−1	−1	+1	+1
98.	+1	+1	+1	−1	−1	−1	−1	+1	+1
99.	+1	+1	−1	+1	−1	−1	−1	+1	+1
100.	+1	−1	+1	+1	−1	−1	−1	+1	+1
101.	+1	+1	−1	−1	+1	−1	−1	+1	+1
102.	+1	−1	+1	−1	+1	−1	−1	+1	+1
103.	+1	−1	−1	+1	+1	−1	−1	+1	+1
104.	+1	+1	+1	+1	+1	−1	−1	+1	+1
121.	+1	−1	−1	−1	−1	+1	+1	+1	+1
122.	+1	+1	+1	−1	−1	+1	+1	+1	+1
123.	+1	+1	−1	+1	−1	+1	+1	+1	+1
124.	+1	−1	+1	+1	−1	+1	+1	+1	+1
125.	+1	+1	−1	−1	+1	+1	+1	+1	+1
126.	+1	−1	+1	−1	+1	+1	+1	+1	+1
127.	+1	−1	−1	+1	+1	+1	+1	+1	+1
128.	+1	+1	+1	+1	+1	+1	+1	+1	+1

ONE-QUARTER REPLICATION B MATRIX

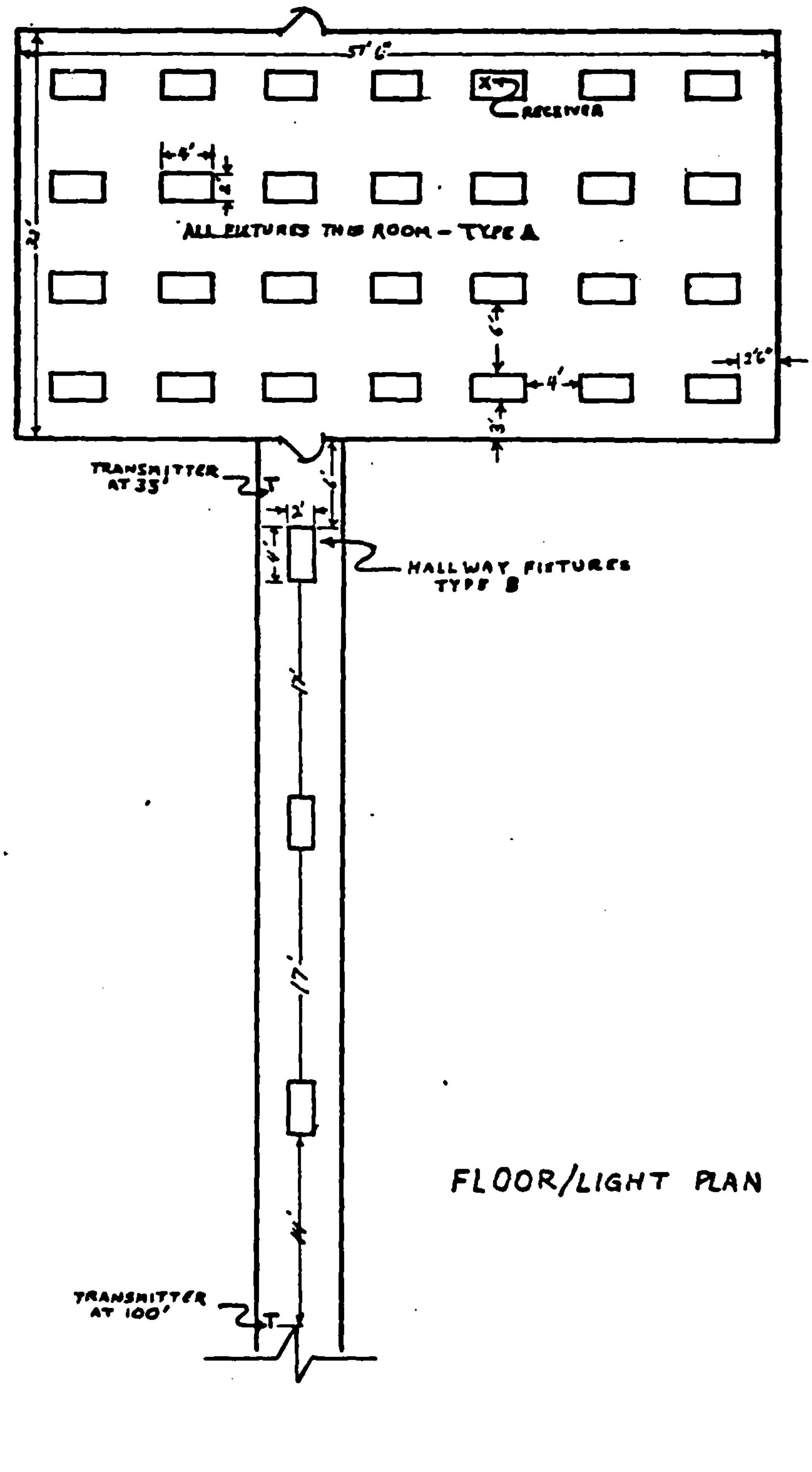
No.	X_0	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
9.	+1	+1	-1	-1	-1	+1	-1	-1	-1
10.	+1	-1	+1	-1	-1	+1	-1	-1	-1
11.	+1	-1	-1	+1	-1	+1	-1	-1	-1
12.	+1	+1	+1	+1	-1	+1	-1	-1	-1
13.	+1	-1	-1	-1	+1	+1	-1	-1	-1
14.	+1	+1	+1	-1	+1	+1	-1	-1	-1
15.	+1	+1	-1	+1	+1	+1	-1	-1	-1
16.	+1	-1	+1	+1	+1	+1	-1	-1	-1
17.	+1	+1	-1	-1	-1	-1	+1	-1	-1
18.	+1	-1	+1	-1	-1	-1	+1	-1	-1
19.	+1	-1	-1	+1	-1	-1	+1	-1	-1
20.	+1	+1	+1	+1	-1	-1	+1	-1	-1
21.	+1	-1	-1	-1	+1	-1	+1	-1	-1
22.	+1	+1	+1	-1	+1	-1	+1	-1	-1
23.	+1	+1	-1	+1	+1	-1	+1	-1	-1
24.	+1	-1	+1	+1	+1	-1	+1	-1	-1
33.	+1	+1	-1	-1	-1	-1	-1	+1	-1
34.	+1	-1	+1	-1	-1	-1	-1	+1	-1
35.	+1	-1	-1	+1	-1	-1	-1	+1	-1
36.	+1	+1	+1	+1	-1	-1	-1	+1	-1
37.	+1	-1	-1	-1	+1	-1	-1	+1	-1
38.	+1	+1	+1	-1	+1	-1	-1	+1	-1

39.	+1	+1	−1	+1	+1	−1	−1	+1	−1
40.	+1	−1	+1	+1	+1	−1	−1	+1	−1
57.	+1	+1	−1	−1	−1	+1	+1	+1	−1
58.	+1	−1	+1	−1	−1	+1	+1	+1	−1
59.	+1	−1	−1	+1	−1	+1	+1	+1	−1
60.	+1	+1	+1	+1	−1	+1	+1	+1	−1
61.	+1	−1	−1	−1	+1	+1	+1	+1	−1
62.	+1	+1	+1	−1	+1	+1	+1	+1	−1
63.	+1	+1	−1	+1	+1	+1	+1	+1	−1
64.	+1	−1	+1	+1	+1	+1	+1	+1	−1
65.	+1	+1	−1	−1	−1	−1	−1	−1	+1
66.	+1	−1	+1	−1	−1	−1	−1	−1	+1
67.	+1	−1	−1	+1	−1	−1	−1	−1	+1
68.	+1	+1	+1	+1	−1	−1	−1	−1	+1
69.	+1	−1	−1	−1	+1	−1	−1	−1	+1
70.	+1	+1	+1	−1	+1	−1	−1	−1	+1
71.	+1	+1	−1	+1	+1	−1	−1	−1	+1
72.	+1	−1	+1	+1	+1	−1	−1	−1	+1
89.	+1	+1	−1	−1	−1	+1	+1	−1	+1
90.	+1	−1	+1	−1	−1	+1	+1	−1	+1
91.	+1	−1	−1	+1	−1	+1	+1	−1	+1
92.	+1	+1	+1	+1	−1	+1	+1	−1	+1
93.	+1	−1	−1	−1	+1	+1	+1	−1	+1
94.	+1	+1	+1	−1	+1	+1	+1	−1	+1
95.	+1	+1	−1	+1	+1	+1	+1	−1	+1
96.	+1	−1	+1	+1	+1	+1	+1	−1	+1

105.	+1	+1	-1	-1	-1	+1	-1	+1	+1
106.	+1	-1	+1	-1	-1	+1	-1	+1	+1
107.	+1	-1	-1	+1	-1	+1	-1	+1	+1
108.	+1	+1	+1	+1	-1	+1	-1	+1	+1
109.	+1	-1	-1	-1	+1	+1	-1	+1	+1
110.	+1	+1	+1	-1	+1	+1	-1	+1	+1
111.	+1	+1	-1	+1	+1	+1	-1	+1	+1
112.	+1	-1	+1	+1	+1	+1	-1	+1	+1
113.	+1	+1	-1	-1	-1	-1	+1	+1	+1
114.	+1	-1	+1	-1	-1	-1	+1	+1	+1
115.	+1	-1	-1	+1	-1	-1	+1	+1	+1
116.	+1	+1	+1	+1	-1	-1	+1	+1	+1
117.	+1	-1	-1	-1	+1	-1	+1	+1	+1
118.	+1	+1	+1	-1	+1	-1	+1	+1	+1
119.	+1	+1	-1	+1	+1	-1	+1	+1	+1
120.	+1	-1	+1	+1	+1	-1	+1	+1	+1

APPENDIX B

FLOOR PLAN AND LIGHTING SPECIFICATIONS



FLOOR/LIGHT PLAN

LIGHTING SPECIFICATIONS

FIXTURE A

Manufacturer: H. E. Williams Products Co.
Carthage, Mo.

Model: HPF Fluorescent Fixture
60 Cycle AC 118 Volts

Light Tubes: Three tubes per fixture
Westinghouse Econowatt
34 Watt Rapid Start Cool White
F40CW/RS/EW-II

Height Above Floor: 9 ft. 7 in.

Light Intensity: 1.57 Watts/sq. ft.

FIXTURE B

Manufacturer: Benjamin Products

Model: C-130,081
60 Cycle 118 Volts

Light Tubes: Four tubes per fixture
Sylvania Cool White Supersaver
34 Watt Rapid Start
F40/CW/RS/SS

Height Above Floor: 8 ft. 8 in.

Light Intensity: 1.1 Watts/sq. ft.

APPENDIX C

RESULTS

ONE-QUARTER REPLICATION A RESULTS

Matrix Number	Number Records Rec'd	Number Records Correct	Number Record Errors Rec'd	Number Records Missed(-) Extra(+)	Percent Correct Records Rec'd
1.	303	303	0	0	100.00
2.	303	303	0	0	100.00
3.	303	303	0	0	100.00
4.	303	303	0	0	100.00
5.	297	288	9	-6	95.04
6.	303	303	0	0	100.00
7.	303	303	0	0	100.00
8.	303	303	0	0	100.00
25.	303	303	0	0	100.00
26.	156	126	30	-147	41.58
27.	0	0	0	-303	0.00
28.	303	303	0	0	100.00
29.	17	0	17	-286	0.00
30.	303	303	0	0	100.00
31.	303	303	0	0	100.00
32.	299	286	13	-4	94.38
41.	303	303	0	0	100.00
42.	303	303	0	0	100.00
43.	303	303	0	0	100.00
44.	303	303	0	0	100.00
45.	303	303	0	0	100.00
46.	303	303	0	0	100.00
47.	302	301	1	-1	99.33
48.	303	303	0	0	100.00
49.	303	303	0	0	100.00
50.	117	106	11	-186	34.98
51.	0	0	0	-303	0.00
52.	303	303	0	0	100.00
53.	0	0	0	-303	0.00
54.	303	303	0	0	100.00
55.	304	303	0	+1 *	100.00
56.	0	0	0	-303	0.00
73.	303	303	0	0	100.00
74.	303	303	0	0	100.00
75.	303	303	0	0	100.00
76.	303	303	0	0	100.00
77.	302	301	1	-1	99.33
78.	303	303	0	0	100.00
79.	303	303	0	0	100.00
80.	303	303	0	0	100.00
81.	303	303	0	0	100.00

82.	0	0	0	-303	0.00
83.	55	12	43	-248	3.96
84.	303	303	0	0	100.00
85.	53	10	43	-250	3.30
86.	303	303	0	0	100.00
87.	304	303	0	+1 *	100.00
88.	0	0	0	-303	0.00
97.	303	303	0	0	100.00
98.	303	303	0	0	100.00
99.	302	300	2	-1	99.00
100.	303	303	0	0	100.00
101.	303	303	0	0	100.00
102.	303	303	0	0	100.00
103.	303	303	0	0	100.00
104.	303	303	0	0	100.00
121.	303	303	0	0	100.00
122.	0	0	0	-303	0.00
123.	291	222	69	-12	73.26
124.	303	303	0	0	100.00
125.	69	53	16	-234	17.49
126.	303	303	0	0	100.00
127.	303	303	0	0	100.00
128.	0	0	0	-303	0.00

---

* Extra records received represent noise not included in original transmission records. These were not included in computation of accuracy percentages.

ONE-QUARTER REPLICATION B RESULTS

9.	303	303	0	0	100.00
10.	303	303	0	0	100.00
11.	303	303	0	0	100.00
12.	300	295	5	-3	97.35
13.	303	303	0	0	100.00
14.	303	303	0	0	100.00
15.	303	303	0	0	100.00
16.	303	303	0	0	100.00
17.	0	0	0	-303	0.00
18.	303	303	0	0	100.00
19.	303	303	0	0	100.00
20.	302	301	1	-1	99.33
21.	295	385	10	-8	94.05
22.	155	110	45	-148	36.30
23.	14	0	14	-289	0.00
24.	303	303	0	0	100.00
33.	303	300	3	0	99.00
34.	303	303	0	0	100.00
35.	303	302	1	0	99.66
36.	303	303	0	0	100.00
37.	303	303	0	0	100.00
38.	303	303	0	0	100.00
39.	303	303	0	0	100.00
40.	303	303	0	0	100.00
57.	61	28	33	-242	9.24
58.	303	303	0	0	100.00
59.	301	297	4	-2	98.01
60.	0	0	0	-303	0.00
61.	302	300	2	-1	99.00
62.	0	0	0	-303	0.00
63.	0	0	0	-303	0.00
64.	303	303	0	0	100.00
65.	298	277	21	-5	91.41
66.	303	303	0	0	100.00
67.	303	303	0	0	100.00
68.	303	303	0	0	100.00
69.	303	303	0	0	100.00
70.	303	303	0	0	100.00
71.	303	303	0	0	100.00
72.	303	303	0	0	100.00
89.	305	295	8	+2 *	97.35
90.	303	303	0	0	100.00
91.	304	303	0	+1 *	100.00
92.	0	0	0	-303	0.00
93.	303	303	0	0	100.00
94.	0	0	0	-303	0.00

95.	0	0	0	-303	0.00
96.	303	303	0	0	100.00
105.	303	302	1	0	99.66
106.	303	303	0	0	100.00
107.	303	303	0	0	100.00
108.	303	303	0	0	100.00
109.	303	303	0	0	100.00
110.	303	303	0	0	100.00
111.	303	303	0	0	100.00
112.	303	303	0	0	100.00
113.	303	303	0	0	100.00
114.	303	303	0	0	100.00
115.	303	303	0	0	100.00
116.	0	0	0	-303	0.00
117.	303	303	0	0	100.00
118.	0	0	0	-303	0.00
119.	302	284	18	-1	93.72
120.	303	302	1	0	99.66

* Extra records received represent noise not included in original transmission records. These were not included in computation of accuracy percentages.

APPENDIX D

ANALYSIS VALUES

ANALYSIS VALUES

Factor Number	Contributing X Variable(s) at High Value (+)	Estimated Beta	z Value	Statistical* Significance
1.	1	-19.57	-11.96	3
2.	2	-0.53	-0.32	0
3.	3	0.32	0.19	0
4.	4	-1.67	-1.00	0
5.	5	-0.18	-0.11	0
6.	6	-19.40	-11.69	3
7.	7	-0.24	-0.14	0
8.	8	0.64	0.39	0
9.	1,2	-0.68	-0.41	0
10.	1,3	0.26	0.16	0
11.	1,4	-1.58	-0.96	0
12.	1,5	-0.22	-0.14	0
13.	1,6	-19.27	-11.78	3
14.	1,7	-0.26	-0.16	0
15.	1,8	0.49	0.30	0
16.	2,3	0.90	0.55	0
17.	2,4	1.00	0.61	0
18.	2,5	-0.40	-0.25	0
19.	2,6	-0.77	-0.47	0
20.	2,7	-3.42	-2.09	2
21.	2,8	-5.39	-3.30	3
22.	3,4	1.92	1.18	0
23.	3,5	-0.34	-0.21	0
24.	3,6	0.13	0.08	0
25.	3,7	-0.27	-0.16	0
26.	3,8	-0.93	-0.57	0
27.	4,5	-0.01	-0.00	0
28.	4,6	-1.77	-1.08	0
29.	4,7	0.05	0.03	0
30.	4,8	-0.70	-0.43	0
31.	5,6	-0.37	-0.23	0
32.	5,7	-1.86	-1.13	0
33.	5,8	0.11	0.07	0
34.	6,7	-0.46	-0.28	0
35.	6,8	0.64	0.39	0
36.	7,8	3.17	1.94	1
37.	1,2,3	0.96	0.59	0
38.	1,2,4	0.92	0.56	0
39.	1,2,5	-0.37	-0.22	0
40.	1,2,6	-0.89	-0.55	0
41.	1,2,7	-3.39	-2.07	2
42.	1,2,8	-5.23	-3.20	3

43.	1,3,4	1.79	1.10	0
44.	1,3,5	-0.23	-0.14	0
45.	1,3,6	0.05	0.03	0
46.	1,3,7	-0.14	-0.09	0
47.	1,3,8	-0.86	-0.53	0
48.	1,4,5	-0.10	-0.06	0
49.	1,4,6	-1.69	-1.03	0
50.	1,4,7	-0.05	-0.03	0
51.	1,4,8	-0.77	-0.47	0
52.	1,5,6	-0.43	-0.26	0
53.	1,5,7	-1.72	-1.05	0
54.	1,5,8	0.15	0.09	0
55.	1,6,7	-0.52	-0.32	0
56.	1,6,8	0.52	0.32	0
57.	1,7,8	3.20	1.96	1
58.	2,3,4	-1.34	-0.82	0
59.	2,3,5	0.69	0.42	0
60.	2,3,6	1.17	0.71	0
61.	2,3,7	-2.05	-1.25	0
62.	2,3,8	-0.30	-0.18	0
63.	2,4,5	2.41	1.47	0
64.	2,4,6	1.02	0.62	0
65.	2,4,7	-0.48	-0.29	0
66.	2,4,8	1.36	0.83	0
67.	2,5,6	-0.12	-0.08	0
68.	2,5,7	1.35	0.83	0
69.	2,5,8	0.47	0.29	0
70.	2,6,7	-3.28	-2.00	2
71.	2,6,8	-5.48	-3.35	3
72.	2,7,8	0.48	0.30	0
73.	3,4,5	0.53	0.32	0
74.	3,4,6	1.92	1.18	0
75.	3,4,7	0.41	0.25	0
76.	3,4,8	0.97	0.60	0
77.	3,5,6	-0.08	-0.05	0
78.	3,5,7	1.70	1.04	0
79.	3,5,8	-0.32	-0.20	0
80.	3,6,7	-0.06	-0.04	0
81.	3,6,8	-1.01	-0.62	0
82.	3,7,8	2.39	1.46	0
83.	4,5,6	0.05	0.03	0
84.	4,5,7	-0.39	-0.24	0
85.	4,5,8	-2.43	-1.48	0
86.	4,6,7	0.09	0.05	0
87.	4,6,8	-0.88	-0.54	0
88.	4,7,8	0.41	0.25	0
89.	5,6,7	-1.70	-1.04	0
90.	5,6,8	0.04	0.03	0
91.	5,7,8	-1.27	-0.78	0
92.	6,7,8	3.15	1.92	1

105.	1,2,6,7	-3.21	-2.68	3
106.	1,2,6,8	-5.35	-4.45	3
127.	1,6,7,8	-3.21	-2.68	3

* 0 indicates not statistically significant.
1 indicates significant at alpha equalto 0.01.
2 indicates significant at alpha equal to 0.05.
3 indicates significant at alpha equal to 0.1.

APPENDIX E

PREDICTED VALUES

PREDICTED VALUES

Factor Number	Contributing X Variable(s) at High Values (+)	Predicted Y Value *	Actual Y Value
1.	1	100.24 **	100.00
2.	2	107.60	100.00
3.	3	90.44	100.00
4.	4	109.27	100.00
5.	5	85.63	94.05
6.	6	87.30	100.00
7.	7	106.73	100.00
8.	8	116.41	100.00
9.	1,2	98.20	100.00
10.	1,3	75.49	100.00
11.	1,4	101.68	100.00
12.	1,5	109.68	97.35
13.	1,6	108.55	100.00
14.	1,7	111.08	100.00
15.	1,8	97.89	100.00
16.	2,3	85.03	100.00
17.	2,4	9.41	0.00
18.	2,5	108.44	100.00
19.	2,6	91.16	100.00
20.	2,7	72.65	99.33
21.	2,8	86.10	94.05
22.	3,4	32.08	36.30
23.	3,5	4.12	0.00
24.	3,6	116.14	100.00
25.	3,7	98.67	100.00
26.	3,8	44.15	41.58
27.	4,5	10.08	0.00
28.	4,6	110.92	100.00
29.	4,7	1.97	0.00
30.	4,8	111.07	100.00
31.	5,6	97.24	100.00
32.	5,7	71.43	94.38
33.	5,8	97.32	99.00
34.	6,7	110.22	100.00
35.	6,8	101.75	99.66
36.	7,8	99.18	100.00
37.	1,2,3	108.71	100.00
38.	1,2,4	99.00	100.00
39.	1,2,5	98.17	100.00
40.	1,2,6	74.72	100.00
41.	1,2,7	105.10	100.00

42.	1,2,8	95.22	100.00
43.	1,3,4	90.93	100.00
44.	1,3,5	103.49	100.00
45.	1,3,6	91.70	100.00
46.	1,3,7	111.68	100.00
47.	1,3,8	109.00	99.33
48.	1,4,5	101.76	100.00
49.	1,4,6	98.26	100.00
50.	1,4,7	28.18	34.98
51.	1,4,8	9.79	0.00
52.	1,5,6	99.04	100.00
53.	1,5,7	1.60	0.00
54.	1,5,8	98.27	100.00
55.	1,6,7	97.32	100.00
56.	1,6,8	12.08	0.00
57.	1,7,8	13.62	9.24
58.	2,3,4	94.67	100.00
59.	2,3,5	89.62	98.01
60.	2,3,6	4.84	0.00
61.	2,3,7	90.27	99.00
62.	2,3,8	-1.62	0.00
63.	2,4,5	1.43	0.00
64.	2,4,6	104.22	100.00
65.	2,4,7	95.63	91.41
66.	2,4,8	101.43	100.00
67.	2,5,6	98.38	100.00
68.	2,5,7	91.27	100.00
69.	2,5,8	104.83	100.00
70.	2,6,7	91.25	100.00
71.	2,6,8	94.67	100.00
72.	2,7,8	104.34	100.00
73.	3,4,5	112.08	100.00
74.	3,4,6	97.32	100.00
75.	3,4,7	98.27	100.00
76.	3,4,8	101.60	100.00
77.	3,5,6	98.37	99.33
78.	3,5,7	109.79	100.00
79.	3,5,8	93.20	100.00
80.	3,6,7	98.26	100.00
81.	3,6,8	101.76	100.00
82.	3,7,8	9.67	0.00
83.	4,5,6	15.64	3.96
84.	4,5,7	91.70	100.00
85.	4,5,8	6.79	3.30
86.	4,6,7	90.93	100.00
87.	4,6,8	95.22	100.00
88.	4,7,8	5.10	0.00
89.	5,6,7	72.07	97.35
90.	5,6,8	98.17	100.00
91.	5,7,8	99.00	100.00
92.	6,7,8	8.71	0.00

105.	1, 2, 6, 7	115. 80	99. 66
106.	1, 2, 6, 8	104. 11	100. 00
127.	1, 6, 7, 8	107. 60	100. 00

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* 95% Bound on the Error equals plus or minus 26. 61
** Percentages reported are predictions. In actuality they must fall between 0. 00 and 100. 00.

FROM: AFIT/CIMI 3 October 1983

SUBJECT: Thesis Transmittal - Major Edwin B. Morgan, Jr.

TO: NR (Ms. June de Souza)

1. The attached thesis entitled "An Exploratory Study of the Use of an Inexpensive Cordless Telephone as a Part of a Data Communications Link" by Major Edwin B. Morgan, Jr., USAF, BSC, is forwarded for your information and action. I would recommend the following individual as reviewer:

Colonel N. C. Nicholas
HQ AFMSC/SGB
Brooks AFB TX 78235

2. Thank you for your assistance.

ROBERT W. PERRY, Captain, USAF, MSC
Program Manager, Health Care Education Div
Civilian Institution Programs

1 Atch
Thesis

8

DTIC